THE
Post Office Electrical Engineers' Journal

THE EQUIPMENT OF THE AGRA TELEGRAPH OFFICE.

N. F. FROME, D.F.C., B.Sc., A.M.I.E.E.

IN a previous number of the Journal (Volume 22, Part 2, page 79) giving a description of the equipment of the Central Telegraph Office, New Delhi, it was mentioned that an adjacent office would be fitted on the same principle of test room working, and this has since been done at Agra.

In designing the equipment for Agra, opportunity was taken to review and improve the New Delhi arrangements; the following notes indicate the chief alterations which were made. The Agra installation is a larger one than that of New Delhi and, in addition to circuit modifications, the lay-out of the plant was also influenced by the fact that most of the load of the Agra Telegraph office is transit traffic.

The trunk test boards, composite set arrangements and testing apparatus are similar to those used at New Delhi (Fig. 1). Closed circuit Morse sets are also arranged in a like manner. Duplex Morse sets, of which 40 have been installed, have been modified in some ways; the circuit (Fig. 2) has been simplified, eliminating the "R/R" key previously fitted, and, in addition, the cross-connection arrangements for repeater working, forked working, etc., are made more convenient. All duplex sets likely to be used for repeater work have been fitted with thermostat alarms allowing distant stations to

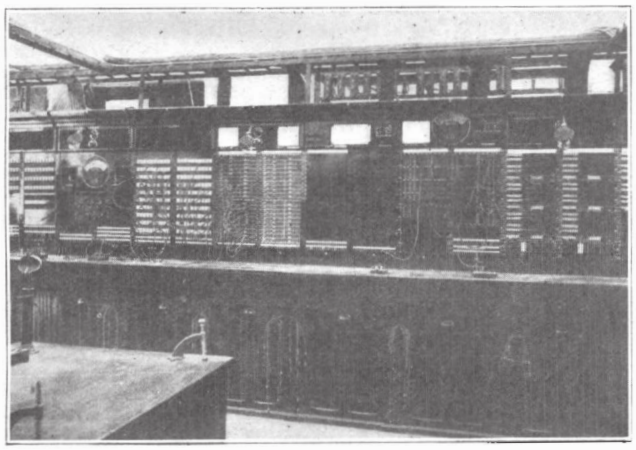


FIG. 1.—TEST AND MORSE BOARDS.

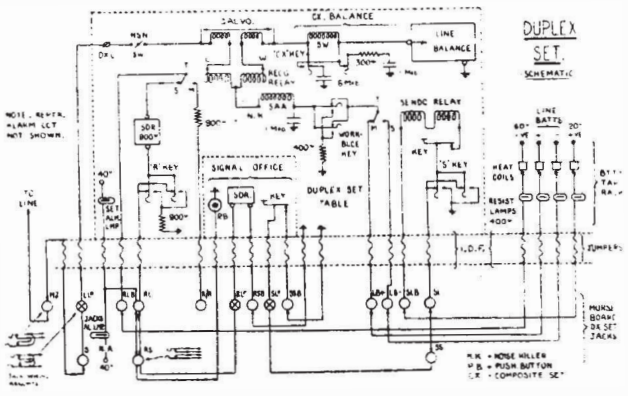


FIG. 2.—DUPLEX SET, SCHEMATIC.

call the supervisor's attention as soon as required.

The Baudot set arrangements have been modified and improved to a greater extent. The sets have been fitted six per table, the distributors and line apparatus being mounted in the centre. The ends of the tables are occupied by the test keyboards, test receivers and small control switchboards (Fig. 3). The latter are fitted with

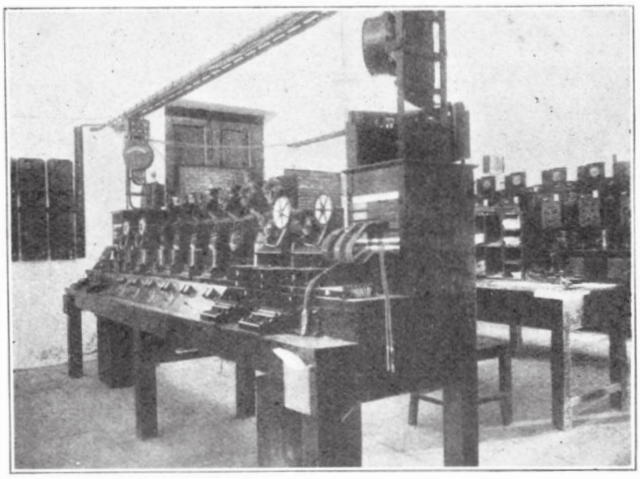


FIG. 3.—BAUDOT SET TABLE.

20-way five-point break jack strips interposed between the distributors and the Baudot Test Boards which form part of the main switchboard of the test room. The wiring arrangement is shown in a schematic form in Fig. 4. The test

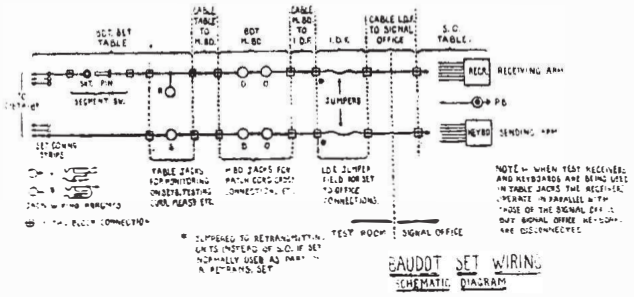


FIG. 4.—BAUDOT SET WIRING.

receivers and keyboards are jack-ended on the control switchboards and can be plugged into the sets with five-way patch cords as required. The control switchboards are used by the Baudot supervisors in attending to set adjustments and faults. The main Baudot test boards contain the jack fields for making all forms of set cross-connections, provision being made to allow as full a flexibility of set and office arrangements as possible. It may be noted that from the series arrangement of jacks used on the control and main test boards, connections made on the latter, whatever they may be, do not influence the regular test procedure on the control boards, thus making the system a simple one to operate. As in the New Delhi office, jacks strips are coloured to further simplify the handling of circuit arrangements. An indication of the results which are obtained from this system may be of interest:—

(1) Any office position can work on any distributor, and working positions can be concentrated in any portion of the office as required.

(2) The keyboards (or transmitters) and receiving arms of all sets can be freely interchanged and apparatus thereby released for investigation of faults.

(3) Keyboards and receivers, distinct from the office equipment, are used for all testing and adjusting of sets, facilitating the location of faults in office apparatus.

(4) Sets can be changed from " correcting " to " corrected," or *vice versa*, without change of office sending and receiving positions.

(5) Two or more copies of the same incoming message can be printed in the office as required.

(6) Any set can be duplexed as required.

(7) Any two sets can be used as a re-transmitting set by locally synchronising them and cross-connecting the two distributors to re-transmitter relays. They can be used with or without a receiving arm connected to the office.

(8) One keyboard (or transmitter) can be used to send simultaneously on a number of sets for transmission of long press messages.

(9) Re-transmitting sets can quickly be arranged for up and down or uni-directional working as required by traffic conditions.

(10) Sets normally worked as re-transmitters can be used as two office terminal sets by cross-connecting to spare office positions.

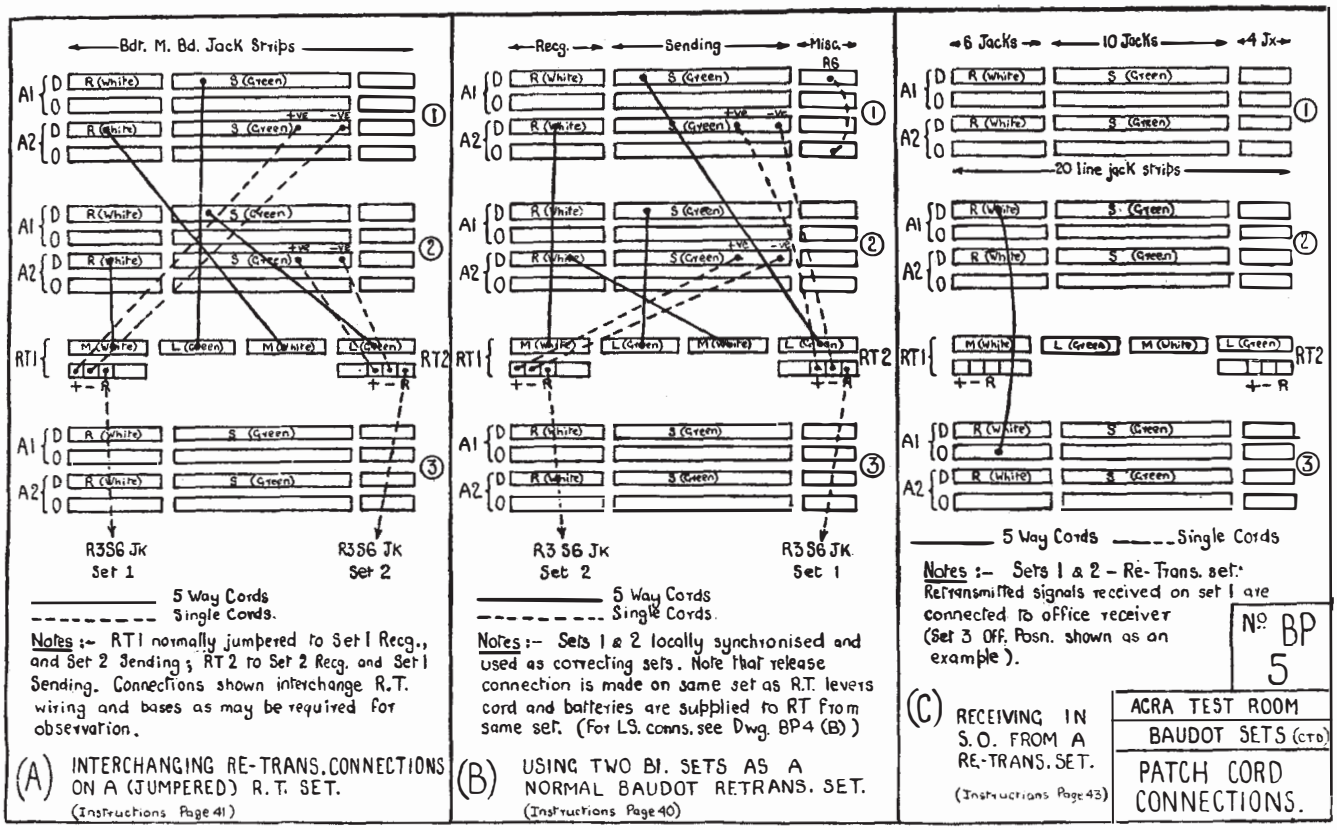

Bdr. M. Bd. Jack Strips
R (White)
S (Green)
M (White)
L (Green)
RT1
RT2
R3S6 Jk
Set 1
R3S6 Jk
Set 2
5 Way Cords
Single Cords.
Notes :- RT1 normally jumpered to Set 1 Recg., and Set 2 Sending; RT 2 to Set 2 Recg. and Set 1 Sending. Connections shown interchange R.T. wiring and bases as may be required for observation.
(A) INTERCHANGING RE-TRANS. CONNECTIONS ON A (JUMPERED) R.T. SET.
(Instructions Page 41)
Recg.
Sending
Misc.
RS
Notes :- Sets 1 & 2 locally synchronised and used as correcting sets. Note that release connection is made on same set as R.T. levers cord and batteries are supplied to RT from same set. (For L.S. conns. see Dwg. BP4 (B))
(B) USING TWO BI. SETS AS A NORMAL BAUDOT RETRANS. SET.
(Instructions Page 40)
6 Jacks
10 Jacks
4 Jx
20 line jack strips
Notes :- Sets 1 & 2 - Re-Trans. set. Retransmitted signals received on set 1 are connected to office receiver (Set 3 Off. Posn. shown as an example).
(C) RECEIVING IN S.O. FROM A RE-TRANS. SET.
(Instructions Page 43)
No BP 5
AGRA TEST ROOM
BAUDOT SETS (CTD)
PATCH CORD CONNECTIONS.

FIG. 5.—PATCH CORD CONNECTIONS.

(11) A number of combinations of forked working with re-transmitter working, etc., can be built up with patch cord connections and a number of extra testing facilities are available.

An example of a patch cord connection diagram (Fig. 5) shows how set cross-connections are made.

The procedure of control of the test room apparatus, alarm working, etc., is similar to that used in New Delhi. The two stations are also linked with a test wire (provided by a composite set) from one test room to the other, giving a direct means of communication for service orders.

FACSIMILE TRANSMISSION IN THE UNITED KINGDOM.

A. T. J. BEARD, A.M.I.E.E.

THE chief systems of Facsimile Transmission in use in the United Kingdom are the Siemens Schuckert, Belin, American Telephone & Telegraph Co., Marconi and Fultograph systems.

Newspapers and the General Post Office are the principal users of the first three systems and use them practically entirely for the facsimile transmission of pictures, the Siemens Schuckert and Belin systems being used for both inland and continental transmissions, and the American Telephone & Telegraph Co. system for inland transmissions only.

Trans-Oceanic communication companies are the principal users of the Marconi system and use it for the facsimile transmission of diagrams and dual coloured matter in which there is no shading.

The Fultograph system is used by various authorities for the facsimile transmission of scientific data and to a lesser extent by news-agencies for the facsimile transmission of pictures.

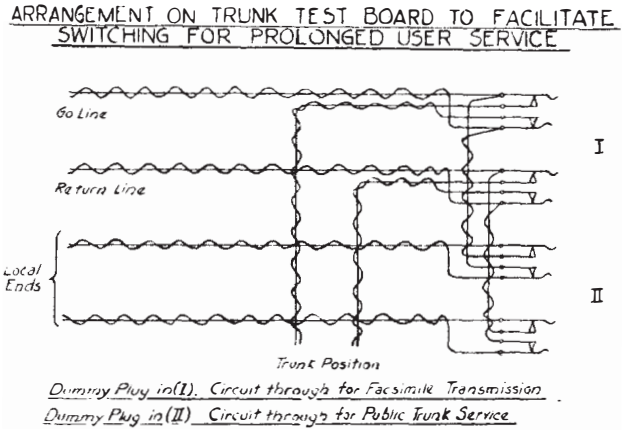

ARRANGEMENT ON TRUNK TEST BOARD TO FACILITATE SWITCHING FOR PROLONGED USER SERVICE
Go Line
Return Line
Local Ends
I
II
Trunk Position
Dummy Plug in(I). Circuit through for Facsimile Transmission
Dummy Plug in(II) Circuit through for Public Trunk Service

FIG. 1.

The land lines required for each of the systems are rented from the General Post Office. Four-wire circuits are generally provided and these are provided on both private wire and prolonged user basis. Private wires are rented between London and Manchester, London and Glasgow, London and Leeds, London and Bristol, London and Liverpool, London and Edinburgh, Manchester and Glasgow, Newcastle and Glasgow, Bristol and Cardiff, etc., the total mileage of circuit provided being approximately 3,000 miles. Prolonged user circuits are rented as required by newspapers and news-agencies between the scenes of special events and the town in which their receiving apparatus is located. The terms "Private Wire" and "Prolonged User" refer to the main portions of the circuits only, the local ends of facsimile transmission circuits are always rented on a private wire basis.

The various systems operate over a frequency range of from 500 to 2,400 periods per second, the frequency band occupied generally being 600 periods per second or less. Wherever possible, in order to keep the equalisation required at a minimum, the Department supplies 4-wire repeatered underground circuits which can be equalised up to 3,000 periods per second; while to keep the circuits as free as possible from cross-talk and interference the main cable portions between terminal trunk exchanges are lined up to zero transmission level.

Prolonged user circuits are chosen from the most suitable trunk circuits on the route concerned and usually have a transmission equivalent of about five decibels. The local ends from the Trunk Exchange to the renter's office are routed *via* local cables and usually have a transmission loss of not more than one decibel. Amplifiers are fitted at the renter's office, but these are used solely for compensating for any loss introduced by the sending or receiving apparatus.

Prolonged user service always obtains for Continental transmissions, the most suitable Continental trunk circuit being released for the facsimile transmission by mutual arrangement between the Administrations concerned.

Pictures are frequently transmitted to more than one receiving station. Two schemes are used, one in which the receiving sets are worked in cascade and the other in which a forked amplifier is used, the receiving stations being joined to either leg of the fork.

Facsimile transmission circuits are not always used solely for the transmission of pictures. Many renters alternate the transmission of pictures with verbal messages and messages transmitted by voice frequency telegraphy.

The present agreement between renters and the General Post Office does not permit the simultaneous use of a facsimile transmission circuit for facsimile transmission and voice frequency telegraphy. Experiments over circuits allocated for facsimile transmission have proved that by the use of suitable filter networks, no difficulty is experienced in transmitting six channels of voice frequency duplex telegraphy or two channels of voice frequency duplex telegraphy and one channel of duplex facsimile.

The slightest interruption to a circuit during the transmission of a picture or the variation of transmission level between the transmission of pictures usually means the spoiling of the picture. Trouble due to interruptions is minimised by the special marking of the associated apparatus at Repeater Stations and other places where the circuits are led out, and by testing circuits only with the concurrence of the renter. Variation in transmission level is kept at a minimum by daily single frequency repeater gain tests, weekly end to end single frequency attenuation tests and monthly valve rejection tests and end to end attenuation tests over a range of frequencies. On routes where spare cable pairs and repeater apparatus exist, emergency facsimile transmission circuits are set up and maintained as real facsimile transmission circuits.

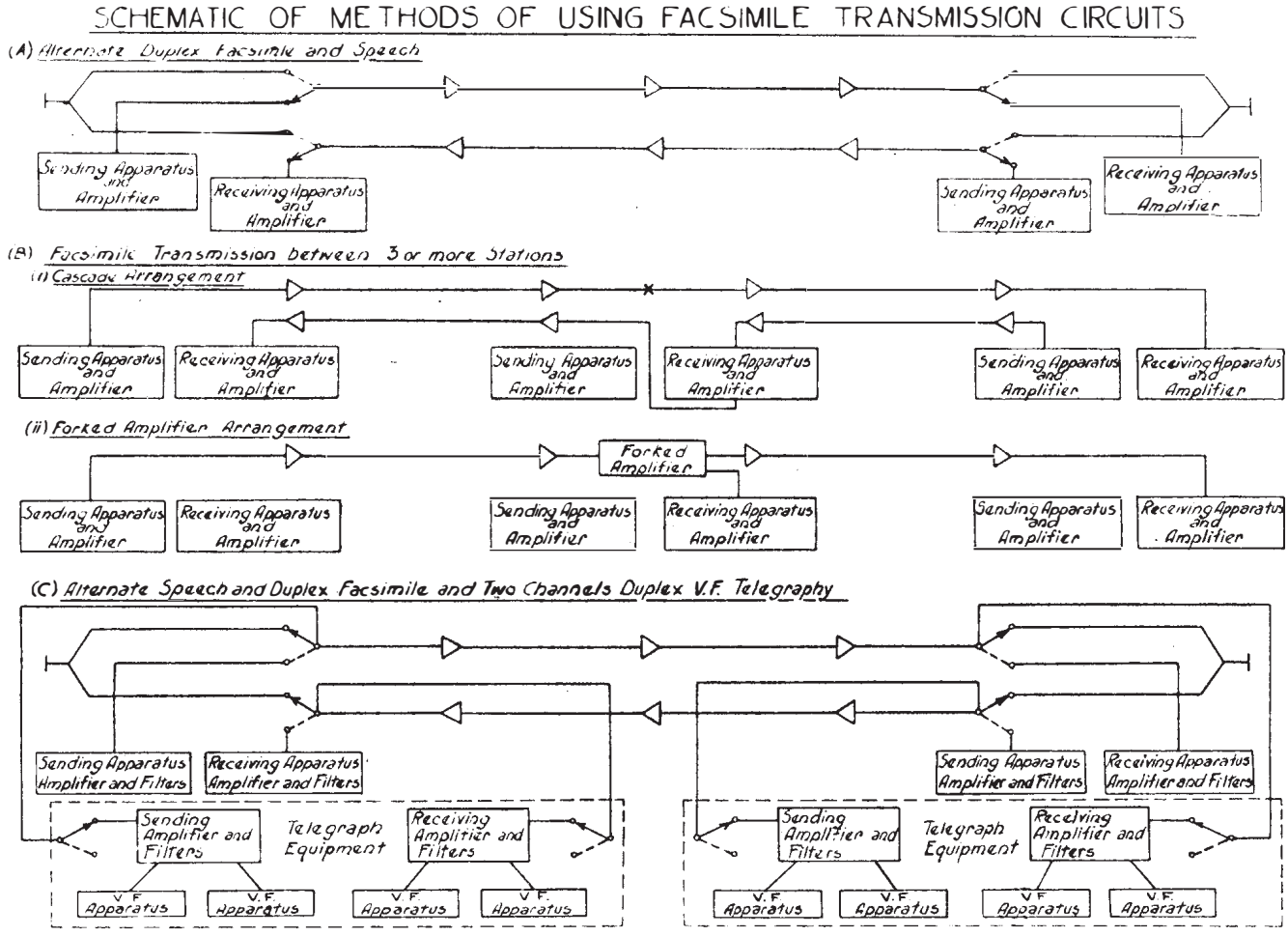

SCHEMATIC OF METHODS OF USING FACSIMILE TRANSMISSION CIRCUITS
(A) Alternate Duplex Facsimile and Speech
Sending Apparatus and Amplifier
Receiving Apparatus and Amplifier
Sending Apparatus and Amplifier
Receiving Apparatus and Amplifier
(B) Facsimile Transmission between 3 or more Stations
(i) Cascade Arrangement
Sending Apparatus and Amplifier
Receiving Apparatus and Amplifier
Sending Apparatus and Amplifier
Receiving Apparatus and Amplifier
Sending Apparatus and Amplifier
Receiving Apparatus and Amplifier
(ii) Forked Amplifier Arrangement
Forked Amplifier
Sending Apparatus and Amplifier
Receiving Apparatus and Amplifier
Sending Apparatus and Amplifier
Receiving Apparatus and Amplifier
Sending Apparatus and Amplifier
Receiving Apparatus and Amplifier
(C) Alternate Speech and Duplex Facsimile and Two Channels Duplex V.F. Telegraphy
Sending Apparatus Amplifier and Filters
Receiving Apparatus Amplifier and Filters
Sending Apparatus Amplifier and Filters
Receiving Apparatus Amplifier and Filters
Sending Amplifier and Filters
Telegraph Equipment
Receiving Amplifier and Filters
V.F. Apparatus
V.F. Apparatus
V.F. Apparatus
V.F. Apparatus
Sending Amplifier and Filters
Telegraph Equipment
Receiving Amplifier and Filters
V.F. Apparatus
V.F. Apparatus
V.F. Apparatus
V.F. Apparatus

FIG. 2.

ENGINEERING RESEARCH IN THE POST OFFICE.

Capt. B. S. COHEN, M.I.E.E., F.Inst.P.

CONSIDERABLE progress has been made in recent years in the Research Section of the Engineering Department both in the number and importance of the researches undertaken and in the extension of plant and buildings. The Research Section deals with all aspects of Electrical Communication and allied matters and in addition a certain number of problems on the postal side involving physical and chemical investigations, such, for example, as the correct lighting and sound proofing of various types of offices, investigating conditions under which certain materials sent by post would be likely to be a source of danger, and so forth.

As is well known, the line of demarcation between Research and Development is, and must of necessity always be, somewhat indefinite and the Research Section deals to some extent with matters of development.

The Research Station is situated on a site of eight acres in extent at an elevation of about 250 feet at Dollis Hill, N.W.2, and in addition there is accommodation at Marshalsea Road, just over Southwark Bridge, and also rooms for Telephonic and Telegraphic purposes situated near the Trunk Exchange in Carter Lane.

When the permanent buildings at Dollis Hill are completed, the accommodation at Marshalsea Road will be given up.

Technical training now comes under the ægis of the Research Section and a special building for this purpose has been erected at Dollis Hill. The work of the Section is now divided into eight groups which are not necessarily enumerated below in their order of importance :—

(1) *Telephone Transmission Lines Group.*—In this group investigations on line problems, the design of Repeaters and carrier systems and so forth, are dealt with. The group works in close co-operation with the Lines Section of the Engineer-in-Chief's office and has an important development function in that it carries out working trials of systems on trunk lines under traffic conditions.

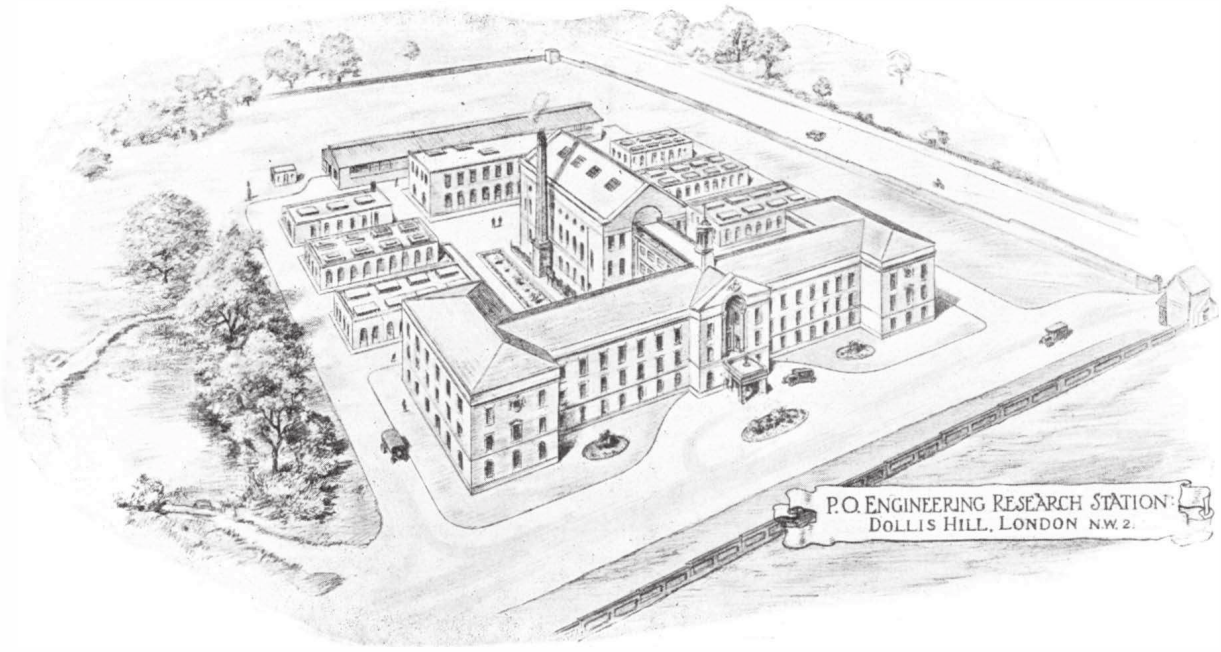


FIG. 1.

Thermionic valve investigations are also carried out by this group.

(2) *Telephone Transmission Apparatus Group.*—This group deals with all investigations involving transmission measurements of telephone instruments and components, local lines and exchange apparatus and circuits, etc., and also with researches on acoustical and

studies of dielectrics, etc., with regard to their application to cable design.

(4) *Exchange Signalling and Equipment Group.*—In this group all research investigations associated with signalling equipment are undertaken. This work includes Automatic Telephone circuit problems and the design and improvement of apparatus used for signalling

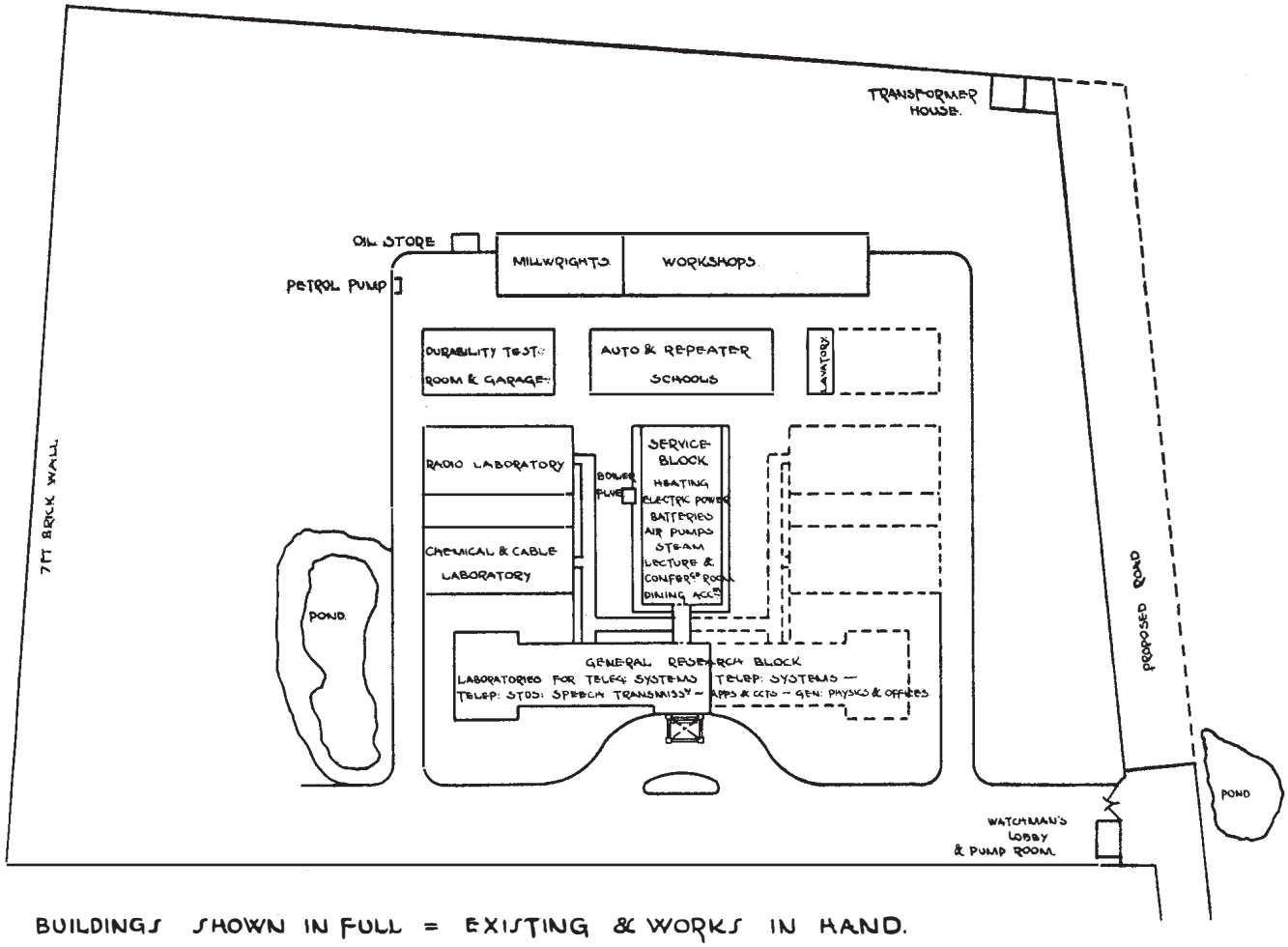


FIG. 2.

electric-acoustical problems and the design and maintenance of telephone transmission standards.

(3) *Cable Research and Acceptance Testing Group.*—The acceptance tests of cables laid and balanced by Contractors and by the Department are carried out by this group, which has at its disposal a fleet of motor vans equipped with precision testing apparatus. The cable group also deals with special faults on land lines and all faults on submarine cables, and carries out

purposes. Durability tests on apparatus and contact material researches also come within the scope of this group.

(5) *Telegraph Group.*—This group is concerned with investigations relating to improvements in existing telegraph apparatus and systems and the critical examinations of new systems and apparatus under working conditions. The group is also concerned with the development of new systems and methods up to the

point at which they may be handed over to the Telegraph Section for operation under traffic conditions.

(6) *Chemical, Physical and Metallurgical Group.*—The work of this group includes all investigations on materials for telephone and telegraph plant involving chemical and physical tests.

Investigations are carried out on corrosion problems and field tests undertaken to provide evidence of damage to Post Office plant by outside power sources. The subject of electrical interference to communication lines by power undertakings, in so far as experimental investigation is required, is also dealt with and precision electrical measurements and calibrations of testing apparatus used in the Research Station are carried out in a laboratory attached to this group. The physical investigations dealt with include those involving the use of mechanical, spectrographic, microscopical and X-ray methods.

(7) *Construction and Maintenance Group.*—The control of the Research Station's Drawing Office and Workshops for the construction of experimental apparatus required for investigations is controlled by this group, which is also responsible for the installation and maintenance of all services required for the work of the Station. The provision and upkeep of the motor vehicles required for the field tests of the Cable Group is also in the hands of the Construction Group.

(8) *Technical Training Group.*—This group is responsible for the carrying out of training courses, which at present comprise:—

Automatic Telephony	11 Classes.
Telephone Transmission	2 Classes
Proby. Asst. Engineers	1 Class.
Probationary Inspectors	1 Class.
Cable Balancing	1 Class.
Precision A.C. Testing	1 Class.
Electrolysis Testing	1 Class.
Teleprinter	1 Class.
Youths-in-Training	— Classes.
Correspondence Classes for Workmen	Winter months.

The officers in charge of these groups are for the most part of Executive Engineer rank. The Station has approximately an engineering staff of 90, an industrial staff of 100, a school staff of 50 and a clerical staff of 16.

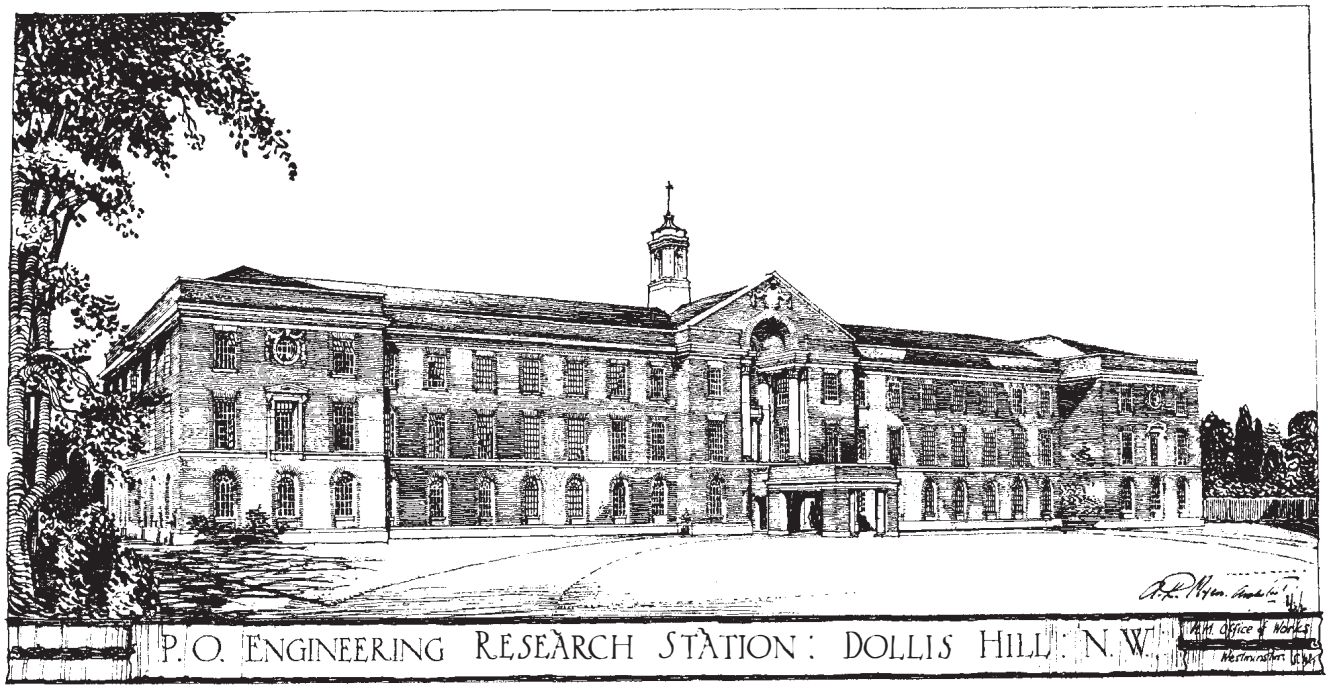


FIG. 3.

The complete building programme is now well under way. Fig. 1 is a perspective view of the

completed station whilst Fig. **2** is a plan showing the alteration of the lay-out of the various buildings. In the latter figure, buildings either completed or in course of actual construction are shown in full line. The buildings are of brick with stone facings and when completed will be well worthy of the traditions of the Department and of the work which they will house.

Fig. **3** shows the elevation of the main building in which the principal communications Research laboratories and a number of administrative offices, etc., will be accommodated. The main entrance is provided with a covered way which will enable visitors to alight and depart comfortably, and delicate apparatus to be exported and imported without damage, in inclement weather. The entrance hall will be panelled in hard wood of Empire origin and from it will lead off the Doorkeeper's and Messengers' rooms, the telephone exchange, corridors and lifts. It may be mentioned that a minor function of these buildings will be to enable the Office of Works architect to incorporate different materials in the structure with a view to determining their suitability for departmental purposes.

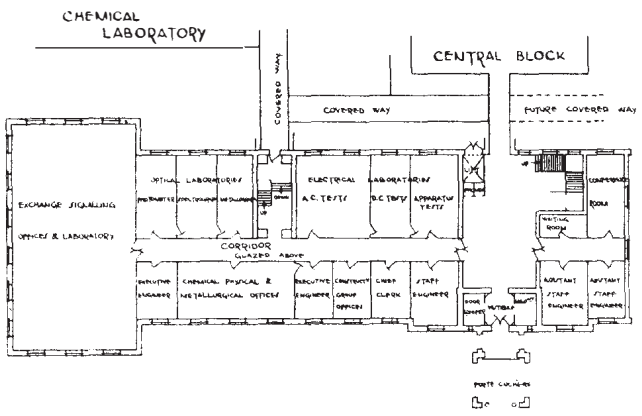


Fig. **4**.

Figs. **4**, **5** and **6** show the allocation of the three floors of the front block, with the exception of about one third of each floor which will be utilised for the Marshalsea Road laboratories and for clerical offices, etc., and the allotment for which has not yet been worked out in detail.

On the ground floor, Fig. **4**, the large laboratory of some 2,400 sq. feet on the left forms the main laboratory for the exchange signalling and equipment group. This group has, in addition, a durability tests laboratory in an outlying building and the use of the complete automatic units

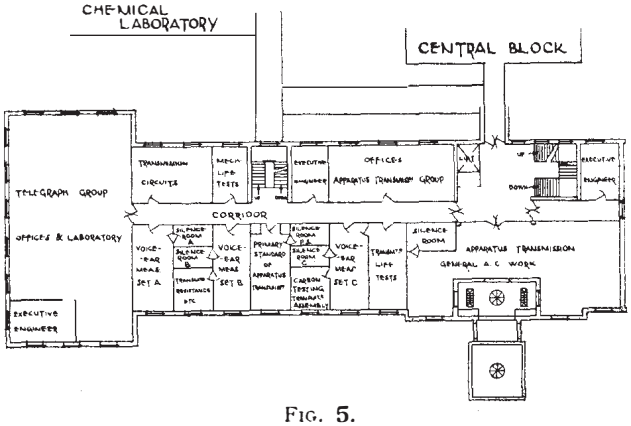


Fig. **5**.

set up in the Automatic Telephone School. There are also on this floor, three optical laboratories devoted to photometric, spectrographic and metallographic and general microscopic work respectively. The three electrical laboratories on this floor are utilized for general electrical tests, A.C., D.C. and apparatus respectively. In these laboratories will be tested all classes of electrical apparatus used generally in the Department and on the Station and for cable balancing and acceptance testing. The remainder of the accommodation is used for administrative staff offices and there is a small conference room with a telephone conference system of the type designed and developed on the Research Station. This system communicates directly with the Alder House Conference Room.

The large laboratory on the first floor, Fig. **5**,

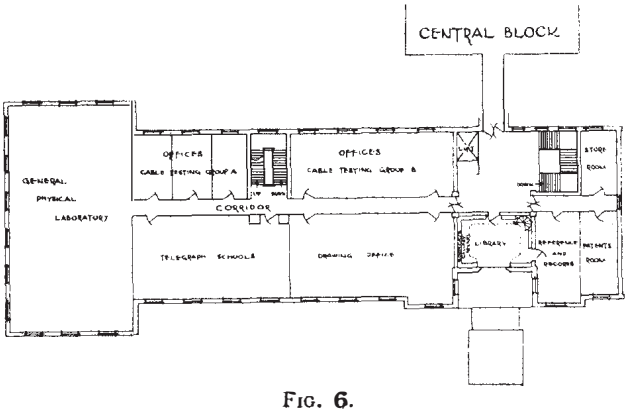


Fig. **6**.

accommodates the Telegraph Research Group. The remainder of the floor is utilized for the Telephone Transmission Apparatus Group. Certain of the laboratories here devoted to voice-ear and electro-acoustical measurement will be sound insulated and rendered non-reverberating, and in some cases will also be electrically screened by the use of expanded metal in the walls, floors and ceilings bonded and earthed.

The voice-ear measurement rooms are also ventilated by ducts connecting with the central tower of the building. The Department's primary reference system of Telephone Transmission will also be installed here.

The second floor, Fig. **6**, contains the general physical laboratory in which is included much apparatus to carry out researches on materials used in electrical communications work. The equipment includes a Moller X-ray apparatus

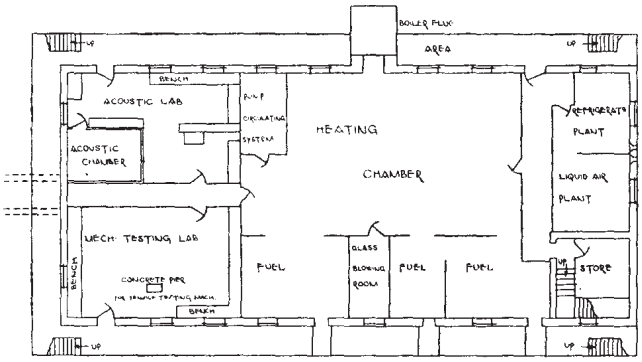


Fig. 7.

for studying the atomic structure of powdered materials such, for example, as carbon granules and a Coolidge tube X-ray outfit for investigating solids by general radiography. On this floor are the offices for the cable testing groups, Group A. research and special faults, and Group B. routine balancing and acceptance tests. A Telegraph school devoted mainly to training in connection with teleprinters, the drawing office and the library are also situated on this floor. The last mentioned has gallery accommodation for books. The library, patents service and record rooms, where abstracts are made of communications articles not covered by the existing published abstracts, form an essential factor in a Research organisation.

The central service block is connected to the centre of the front block by means of corridors.

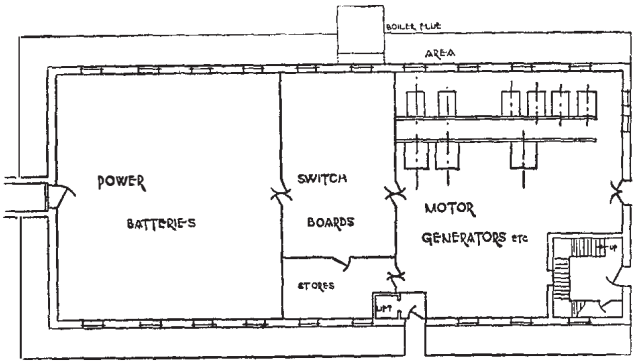


Fig. 8.

The service block has a basement and three floors, see Figs. **7**, **8**, **9** and **10**. In the basement, Fig. **7**, is accommodated the heating plant and hot water supplies for the greater part of the station. A plant for the production of liquid air and a refrigerator are also installed here.

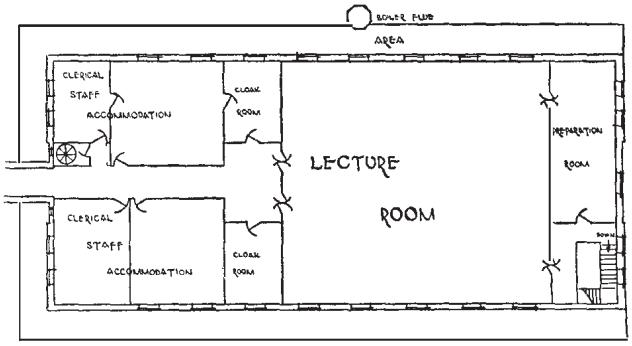


Fig. 9.

A specially built laboratory for acoustical and electro-acoustical research in this part of the building is of particular interest. This has an inner chamber of brick lined with celotex and about two foot thicknesses of Gamgee tissue, a species of cotton wool. There is practically no

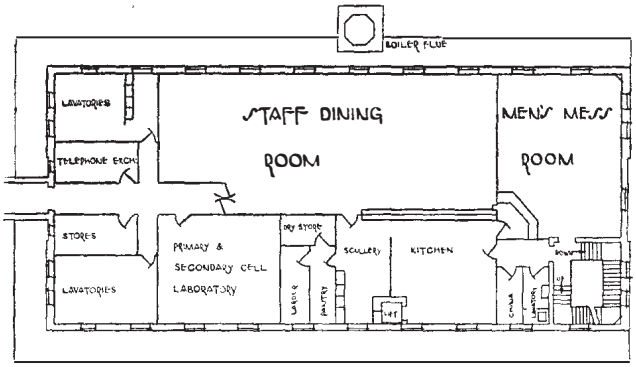


Fig. 10.

acoustic reflection from the inner walls of this room so that measurements carried out inside are apparently the equivalent of measurements carried out in space. This room is utilised for such fundamental measurements as the acousto-electric ratios of transmitters and receivers including loud speakers. As an illustration of the effect caused by even a slight amount of internal reflection Fig. **11** shows (·) the smooth curve obtained by measuring a constant volume sound at 4000 periods per second at varying distances

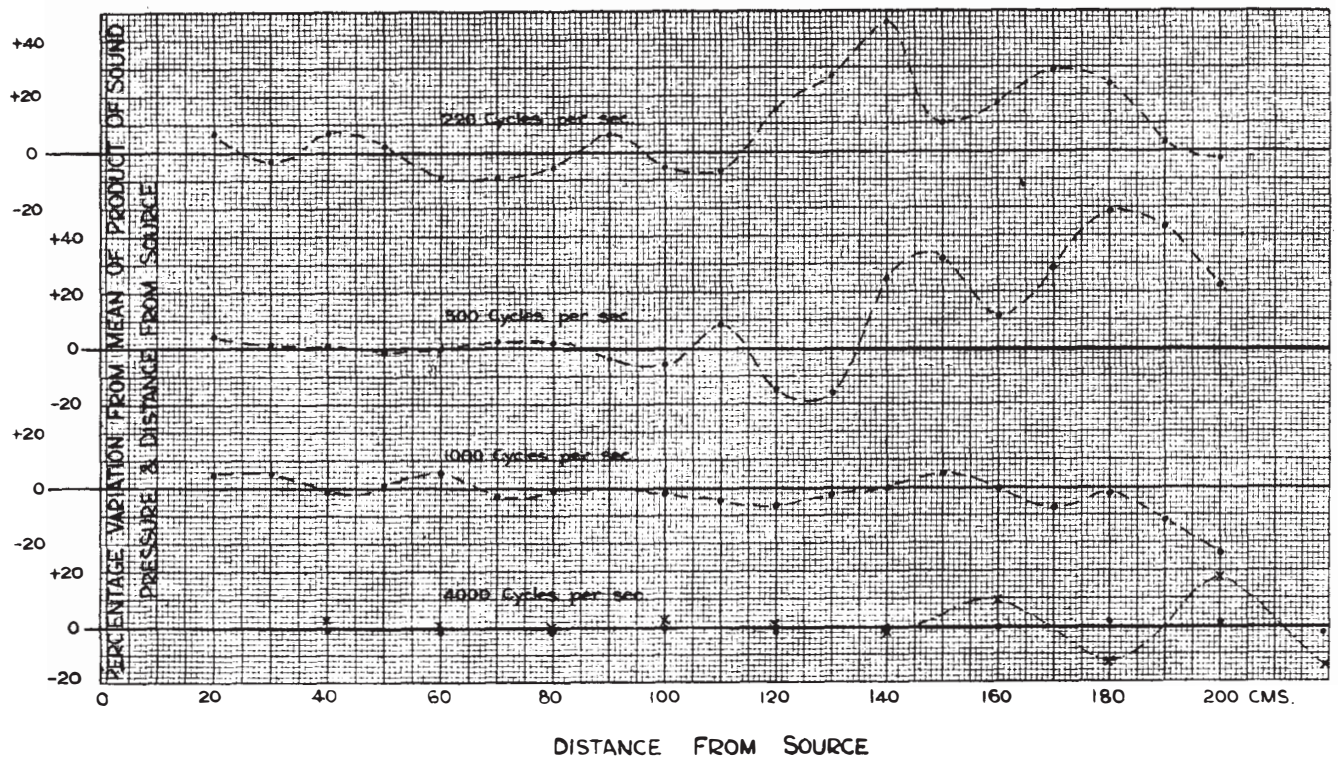


FIG. 11.—SOUND FIELD EXPLORATIONS IN ACOUSTIC CABINET.

inside the room and (x) the same measurements repeated with a piece of fibre matting about five sq. ft. in area introduced into the interior. The irregular curve indicates considerable reflections which would vitiate any measurements made. An equipment of apparatus in this laboratory of special interest enables the frequency amplitude characteristics of transmitters, receivers and loud speakers to be photographically recorded over the complete audio range by the mere rotation of a handle. A general view of this apparatus is shown in Fig. **12.**

The only other laboratory on the basement floor is devoted to mechanical testing and is equipped with a tensile testing machine for metal rods of small diameter. There is a similar machine for testing telegraph strip paper. There are also Brinell hardness testers, apparatus for testing fatigue of materials and some small electric furnaces.

Fig. **13** is a general view of this laboratory.

The ground floor of the central service block, Fig. **8,** is allotted to power supplies for the whole station and comprises a motor-generator room in which is also installed telephone frequency alternators and power ringing generators. The two largest generators have each a capacity of 15 kW at 300 volts and there are 11 other sets with varying capacities and voltages.

The central room contains the main A.C. switchboard and necessary D.C. switch gears in five bays. The main supply is 3-phase A.C. obtained from the Willesden Corporation and transformed on the station down to 415 volts.

The third room on this floor contains the storage batteries. Various makes of cell are used and there are two main batteries of 240 volt, 250 A.h., and other batteries giving voltages ranging from 12 volt to 150 volt, and capacities

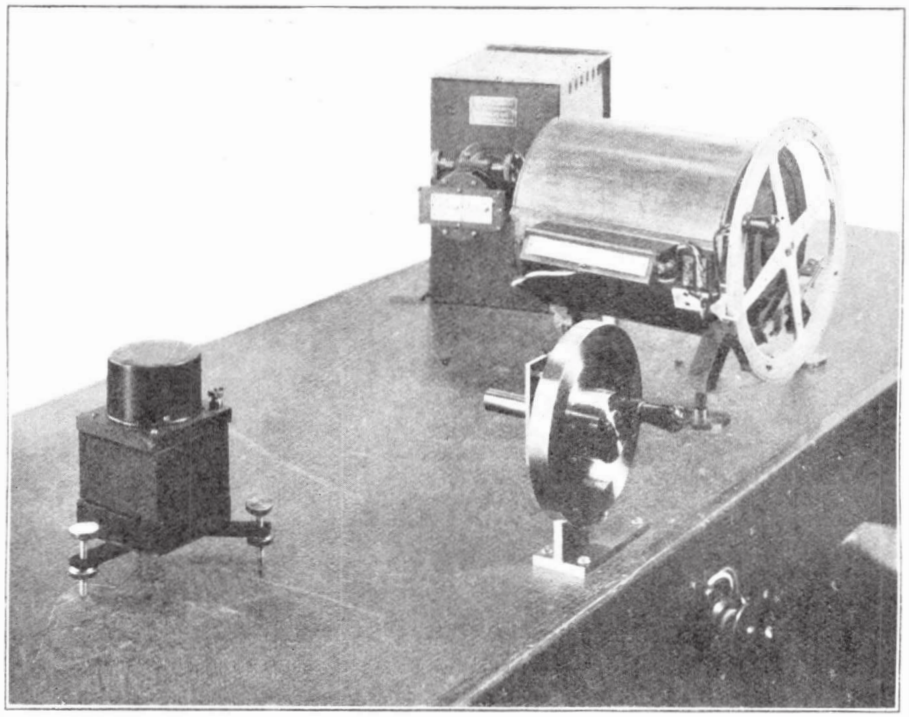


FIG. 12.

from 16 A.h. to 1000 A.h. In addition to the supplies from these batteries, which are distributed to all laboratories, a certain number of separate batteries and cuprous oxide rectifier chargers are located with the plant which they supply in order to minimise interference.

The first floor, Fig. **9**, will be ultimately arranged to accommodate one small laboratory devoted to primary cell research and the remainder of the space will be wholly utilised for the Dining Club, the technical staff canteen and the associated kitchens, etc., which at the moment only occupy a part of this floor. This extension is partly necessitated by the influx of about 200 students and staff in the technical schools.

FIG. **13**.

The second floor, Fig. **10**, has a large conference room and lecture theatre, illustrated in Fig. **14**. This is probably one of the finest rooms situated in any Post Office premises, and although so pleasing in appearance, is constructed with every regard to economy. The panelling of the walls and the doors, for example, are in stained Columbia pine, a cheap, soft wood which, however, gives the impression of handsome and harmonious finish. The floor is in an Indian hard wood, taking a dark red brown polish. The semi-cylindrical roof is lined with acousticos felt, linen covered and white distempered, and the presence of this felt considerably reduces the reverberation time. A moving picture projector is operated from a fireproof room on the third floor, and the upper part of the end wall of the theatre forms the screen.

The 10 oriel windows have opaque curtains for darkening, and at the same time the electrically controlled blinds covering the four roof lights can be operated from the lecture table.

Within a fortnight of the completion of this room, it was required for use in connection with

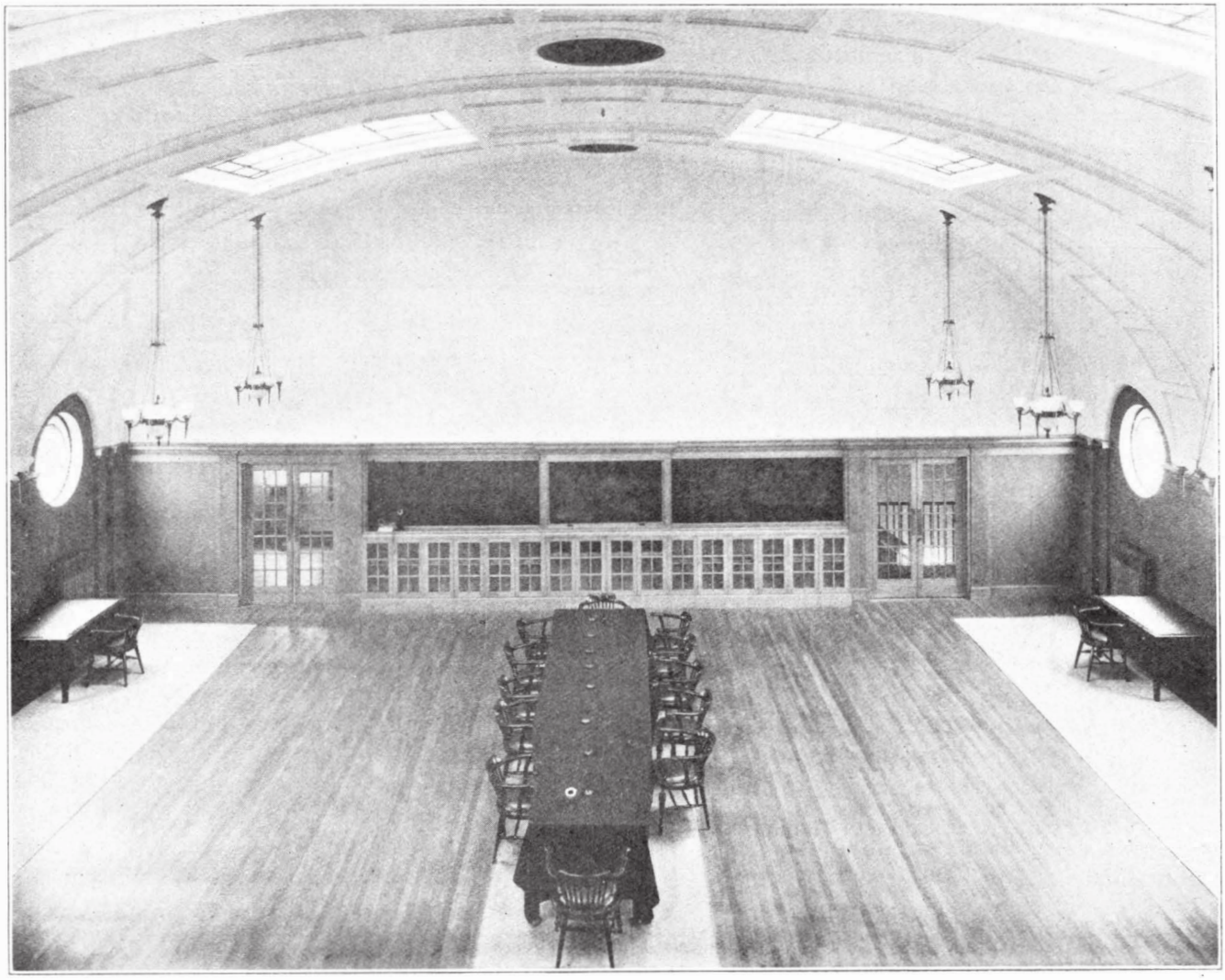


FIG. 14.

with an International Conference on power disturbance, and it has been in constant use for various committee meetings, technical classes and for the showing of educational films, of which more anon.

The remaining rooms on this floor are in use temporarily for offices and library accommodation pending the completion of the front block.

The top attic floor, Fig. **15**, is devoted to photographic purposes and includes the fireproof room housing the moving picture projector. There is a well-lighted studio for taking pictures of apparatus required for issue with Research reports and a series of developing and printing rooms. The Research Section has taken a number of educational films dealing with such subjects as cable jointing, pole shifting, etc., and is at present engaged in completing a multi-reel film with talking accompaniment, entitled "The Engineering of a Telephone System." Experience is undoubtedly

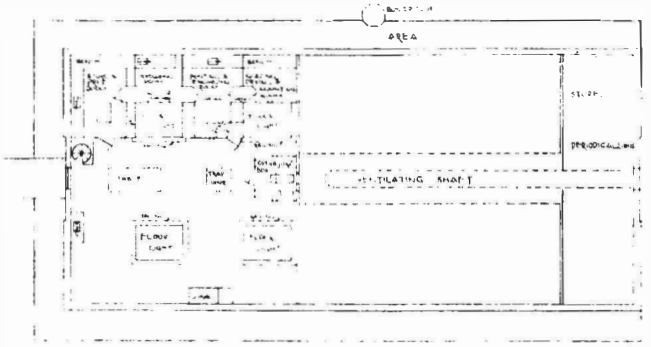


FIG. 15.

showing that much information can be imparted by the aid of the film more rapidly and economically than by any other method.

We now come to the outlying buildings which will be linked up to the main buildings by covered ways of the cloister type. The roofs of these covered ways carry the various services such as electric light and power, gas, etc.

As mentioned in the beginning of this article, the Research Section deals with Technical training and the various training courses were enumerated.

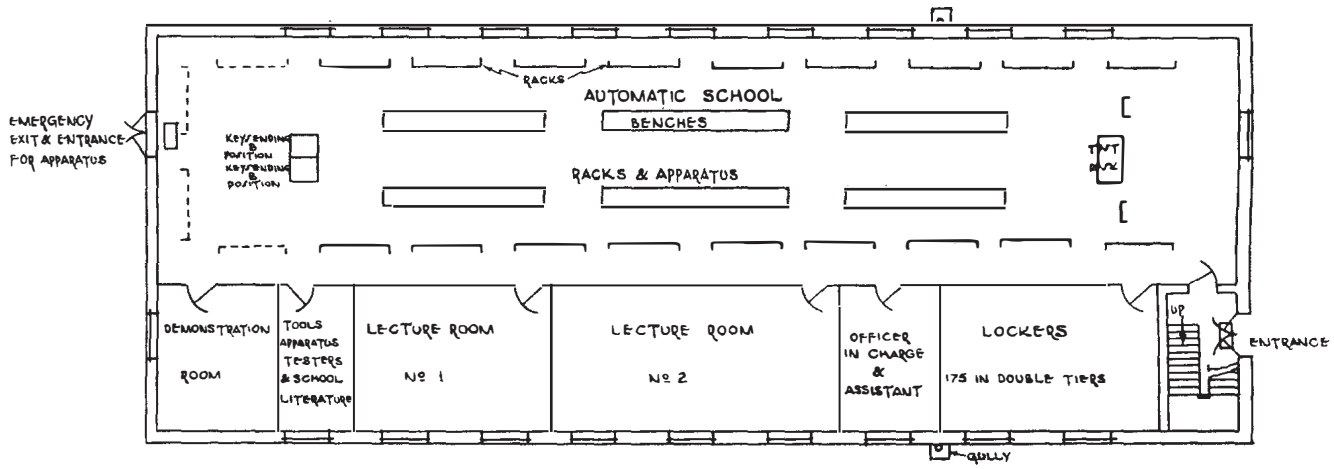


FIG. 16.

telephone exchange demonstration room fitted with units of all the systems in general use in the Department. These units can also be connected by junction lines to the exchange signalling research laboratories, thus rendering it possible for the latter to carry out researches involving the introduction of any type of standard automatic circuit. On the ground floor are also a number of small lecture and demonstration rooms.

The upper floor, Fig. **17**, includes the Telephone Repeater School demonstration room, and

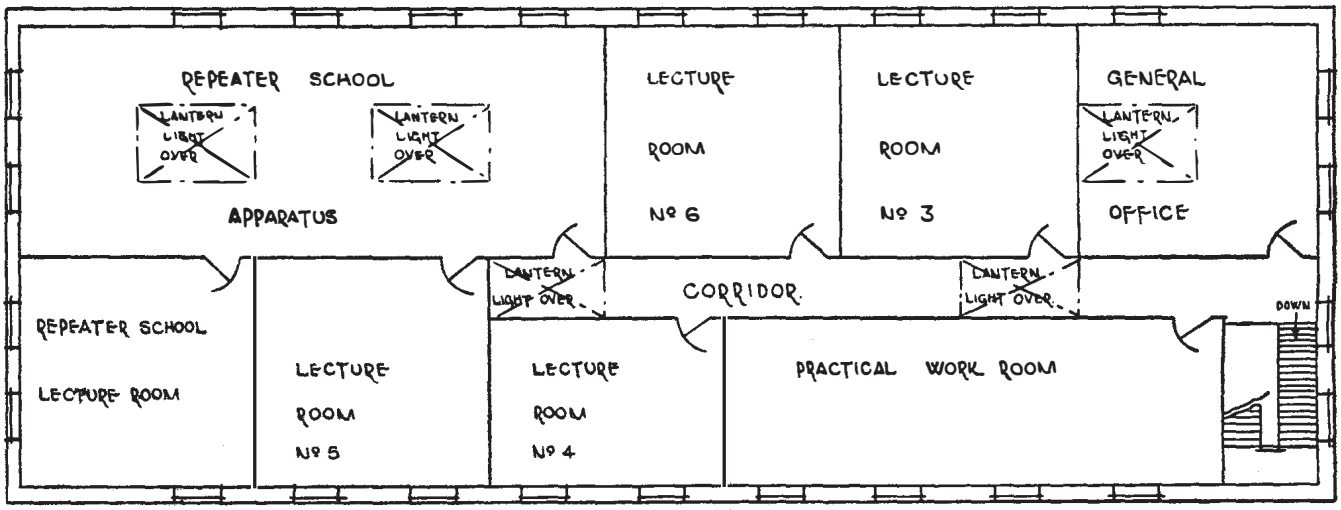


FIG. 17.

An outlying building of two stories accommodates the greater part of the training work. Fig. **16** is a plan of the ground floor of this building, which comprises a large automatic further lecture rooms and training staff office accommodation.

Fig. **18** is the plan of one of the one-storey buildings which includes chemical laboratories.

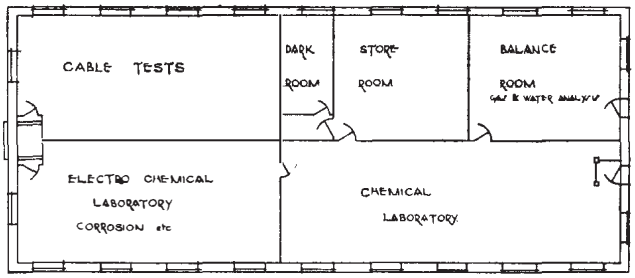


FIG. 18.

One of these is mainly devoted to corrosion and electrolysis researches, subjects which unfortunately loom largely on the communication engineer's horizon. Included here are chambers in which samples of materials or apparatus can be subjected to saline atmospheric conditions and also such salubrious airs as occur in the vicinity of certain manufacturing cities such as Widnes. An adjacent laboratory in this building will be devoted to cable research including cable dielectric and continuous loading material investigation.

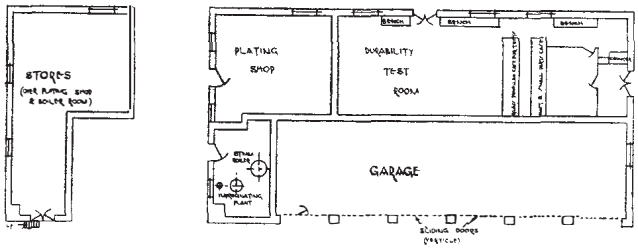


FIG. 19.

Fig. **19** is the plan of another of the outlying buildings, a considerable part of which forms a durability test room for automatic telephone apparatus, which can be operated continuously under controlled conditions. Records of interruptions and their causes are kept and at the end of a certain number of operations, usually running into the millions, the apparatus can be dismantled and the component parts subjected to detailed examination which may involve mechanical, chemical, metallographical and microscopical tests. This building also contains the garage, which accommodates the testing vans and station transport. The latter includes an omnibus which carries out a daily service between Dollis Hill and Alder House. The test vans are used in connection with cable balancing and acceptance testing, also for electrolytic surveys and any other tests required on the road. Smaller rooms in this building contain deposition plant for electro-plating with various metals and here also will be found a coil impregnating plant and a paint spraying outfit.

Fig. **20** is a plan of the workshop in which practically any form of apparatus or equipment required for research purposes can be constructed and, in addition, the plant and staff is sufficient to enable a small number of any piece of apparatus to be constructed in a reasonably short time for development purposes. As an example, the Telephone Instrument Efficiency Testing outfit, T.I.T., was designed in the Section and four sets have been turned out in the Workshop for use at testing depots, etc. A detailed description of this apparatus forms the subject of a special article on pages 31 to 36 and is quoted here with the view of indicating a typical example of the more complex and elaborate apparatus constructed on the Station for research and development purposes. Reverting to Fig. **20**, it will be observed that the workshop includes a large machine and fitters' shop and a wood working shop. These are well equipped with labour-saving tools. There is also a coil winding shop in which a small staff is kept busy with the multifarious coil winding requirements for communication research. One end of the workship buildings provides separate accommodation for the Millwrights and this portion is equipped with some heavy tools such as a pneumatic hammer and also a forge.

This article describes in a general manner the scope and lay-out of the Research Station and includes brief references to some of the plant and research apparatus. It is hoped in a further article to give some indication of the more important development and methods which have been introduced into the Service as a result of the activities of the Research Section. It may be mentioned, however, in conclusion, that an analysis of the more important researches carried out about three years ago during the preceding years indicated that they could be divided into two groups. In the first group, consisting of approximately one third, it was found fairly easy to allot a monetary value to the research, either by virtue of a definite saving in maintenance or by the introduction of a new service or channel and so forth.

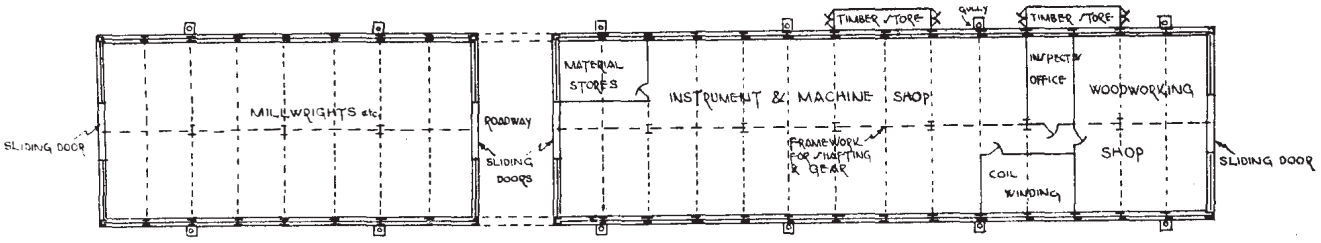


FIG. 20.

With respect to this group of researches an estimated annual saving to the Department exceeding £150,000 was indicated and the remaining two-thirds researches, whilst more difficult to define in terms of pounds, shillings and pence, included many investigations the results of which it had been found necessary or advisable to incorporate into the Department's service, and also work which would have to be done elsewhere if not done by Research staff. As the overall annual costs of the Research Station plant and staff does not exceed £75,000 per annum it will be realised that the Research Section may be regarded as a highly successful business organisation paying a handsome profit.

A further investigation of the results of the work done last year, on the same basis as the above, showed a direct saving of £128,000 per annum, while important research and development work now in hand gives promise of very considerable reductions, both in capital expenditure and in annual maintenance charges.

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM.

TELEPHONES AND WIRE MILEAGES, THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 31ST DEC., 1930.

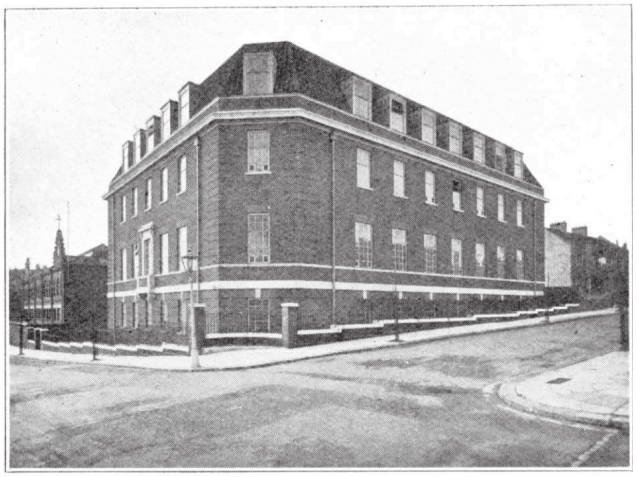
No. of Telephones owned and maintained by the Post Office.	Overhead Wire Mileage.				Engineering District.	Underground Wire Mileage.			
	Telegraph.	Trunk.	Exchange.	Spare.		Telegraph.	Trunk.	Exchange.	Spare.
699,105	593	3,945	53,713	132	London	25,247	99,817	2,703,690	69,401
93,887	2,227	21,749	71,599	2,189	S. Eastern.	4,057	65,299	288,965	37,498
97,449	4,488	32,856	68,781	3,884	S. Western.	22,889	19,675	215,659	67,957
78,694	6,258	39,895	72,829	7,020	Eastern.	24,697	49,605	167,639	59,519
110,982	9,624	45,788	68,490	4,597	N. Mid.	33,708	72,347	288,033	96,057
97,576	4,807	31,985	83,659	3,990	S. Mid.	13,865	40,699	239,066	76,954
64,024	4,331	29,942	61,524	4,077	S. Wales.	7,244	32,654	145,798	66,132
121,515	7,920	27,231	58,244	4,548	N. Wales.	13,958	46,723	331,321	105,986
174,250	1,412	15,913	45,678	3,232	S. Lancs.	14,865	93,048	557,907	68,087
103,990	6,010	30,519	51,775	3,609	N. Eastern	15,186	53,334	287,368	68,879
70,610	3,804	24,015	41,881	2,946	N. Western.	7,947	38,315	183,955	41,979
53,531	2,443	16,059	28,324	3,189	Northern.	8,491	23,667	148,220	35,453
24,680	4,411	9,224	15,162	622	Ireland N.	136	3,163	58,090	2,405
74,931	4,744	28,234	43,812	1,368	Scotland E.	7,572	19,838	170,319	37,606
97,616	7,242	25,203	46,942	1,139	Scotland W.	11,992	30,694	249,030	33,876
1,962,849	70,314	382,558	812,413	46,542	Total	211,854	685,878	6,034,160	867,780
1,937,869	70,664	380,758	801,943	45,757	Figures as at 30 Sept., 1930.	209,635	658,766	5,900,174	832,924

ACORN EXCHANGE.

"The Acorn which 'scatters great hopes in the seedfield of man.'"—BROWNING.

PROGRESSIVE INSTALLATION OF THE NEW STANDARD OPEN TYPE RACKS AND SHELVES.

B. HOUGHTON BROWN,
Engineering Division, Standard Telephones and Cables, Limited.



ACORN EXCHANGE.

ACORN EXCHANGE, situated in Lexden Road, High Street, Acton, consists of a three-storey building housing an initial equipment of 4,600 lines of Step-by-Step equipment, with an ultimate capacity of 10,000 lines, and holds the distinction of being the first Exchange to be installed utilising throughout British General Post Office "Standard Open Type" (single-sided) racks as described by Mr. G. Brown in his article in this Journal, dated April, 1930. The equipment is arranged on three floors as follows:—

1st floor—Offices and Apparatus Room.
2nd floor—Power Plant, Battery Room and Apparatus Room.
3rd floor—Offices and Manual Room.

Manufacture and installation are being carried out by Messrs. Standard Telephones and Cables, Limited, Hendon, and this article is intended as a follow-up of Mr. G. Brown's article referred to above to show, with the assistance of a series of photographs, how the Engineer-in-Chief's drawings and specifications have been interpreted and put into actual practice.

At the time of writing, there are two distinct divisions of opinion concerning the method to be adopted in handling the " Open Type " racks and equipment. One is in favour of shipping fully equipped and wired racks direct from the factory, and the other is in favour of making full use of shelf unitisation, and shipping in three distinct batches consisting of (1) racks and cables, (2) shelves, and (3) apparatus. The latter method has been adopted for the installation under review, and it is hoped that, as the installation progresses, the advantages of this method will be apparent. To this end the photographs are being taken at stated intervals of the installation, and it is intended to carry this through until the completion of the Exchange.

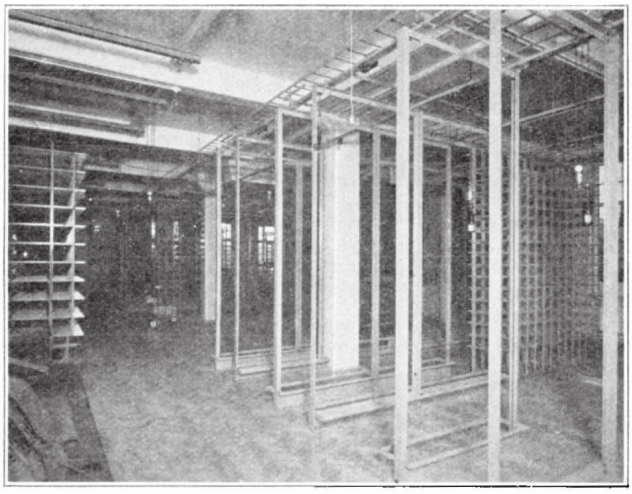


Fig. 1.

The immediate impression obtained from the photographs is the absence of the large independent framework structures with which we are so familiar in other automatic exchanges. Line and Final Units and Trunk Boards are replaced by a series of racks of such similar construction that when unequipped, unless you are sufficiently expert to be able to read the drillings on the rack uprights, it is impossible to tell what function they are destined to serve in the exchange.

The racks throughout the exchange are 10′ 6″ high and vary in width only, as detailed by Mr. G. Brown. The construction of the subscribers' uniselector rack, which, by the way, is not a new monster introduced into the telephone world, but merely a rack carrying what in the old days were known as " Rotary Line Switches," " Preselectors," or " Subscribers' Line Switches," and which have now been re-christened " Uniselectors," is identical with all other racks in the exchange.

Since, as previously stated, the photographs are intended to show the progressive installation of an automatic exchange built up on the " piece-meal " basis, we will deal with the advantages claimed for this scheme and will then show, by means of the photographs, how they have been utilised.

1. The greatest advantage in the eyes of the author is undoubtedly the fact that by shipping the framework to the exchange in advance of the apparatus

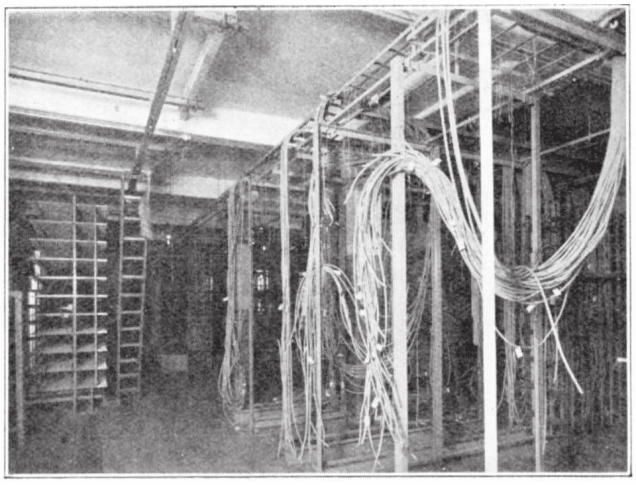


Fig. 2.

the installation and shop periods are allowed to overlap, whereas in the bulk shipment methods the installer can do practically no work until the most detailed piece of apparatus has been manufactured, thereby losing many valuable weeks.

2. Secondly, the question of handling must be considered, and here again the " piece-meal " method seems to have considerable advantages, as no expensive haulage tackle is necessary, the frameworks being shipped broken down and the heaviest item being the unit of two unequipped shelves.
3. Thirdly, all ceiling and wall supports,

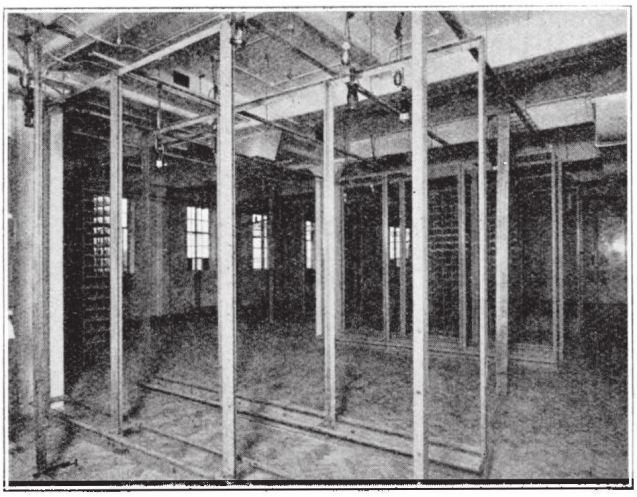


FIG. 3.

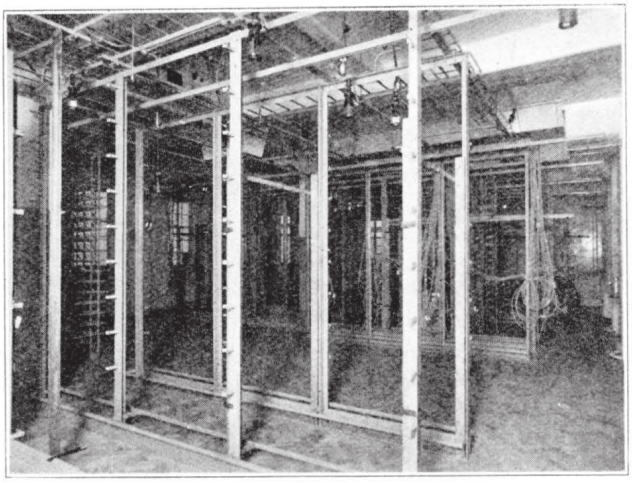


FIG. 4.

where such are necessary, can be fixed before the apparatus is in the building, thus avoiding damage due to dust and dirt and the presence of heavy scaffolding, etc.

In addition to the advantages gained by "piece-meal" shipping, there are a number of inherent advantages in the "open type" racks themselves. Briefly these are as follows:—

1. The racks being all of the same height enable a flat and even cable runway scheme to be employed and facilitate rack-to-rack bracing with the minimum disturbance to the walls and ceilings.
2. The uniformity of width of the racks greatly assists supervisory arrangements. The ideal exchange lay-out consists of long main aisles with cross aisles at regular intervals, thus giving efficient supervision with the minimum amount of apparatus and cable. This is more nearly obtained with these racks than is possible with individual double-sided structures, particularly where these require a gangway at the end as well as at the sides, and, with an ideal floor, perfect exchange supervision now comes within the realm of practical politics.
3. Advance information to enable the floor chases to be cut to receive the frames is no longer necessary, since all racks and frames, with the exception of the Main Distribution Frame, stand on the wood-block surface.

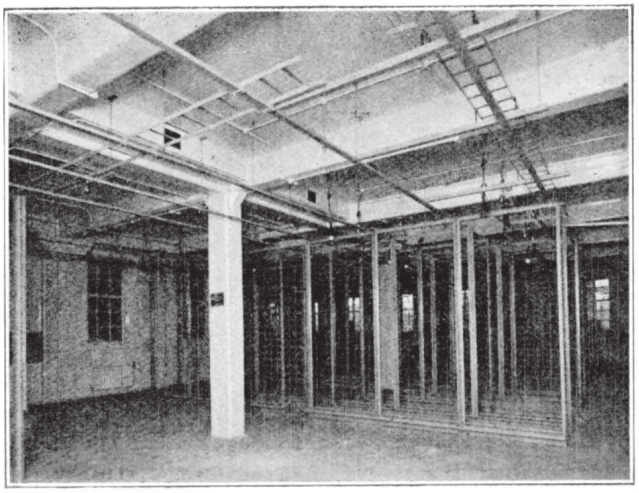


FIG. 5.

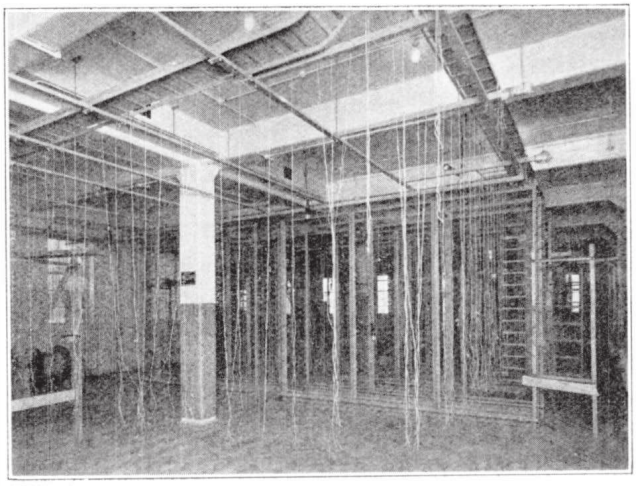


FIG. 6.

4. The use of a continuous foot upon which the racks are mounted not only distributes their weight, causing a saving in the cost of building construction, but also reduces the possibility of dust collecting in inaccessible positions to a minimum.
5. With the exception of the Trunk Distribution Frame, the dimensions of which do not line up with the remainder of the racks and which is at present being re-designed, a considerably improved floor plan lay-out is made possible.

The photographs covered by Figs. **1—8** show the first two stages of the installation. Figs. **1**, **3**, **5** and **7** were taken immediately after the rack frameworks had been assembled and bolted to the continuous angle foot. It is perhaps worthy of mention that at this stage of the work the necessity for absolutely level floor surfaces became apparent. At Acorn the floors were not perfectly level and packing strips had to be cut and fitted before the racks could be erected.

Figs. **2**, **4**, **6** and **8** were taken at a later date, when a large percentage of the cables had been run in.

Fig. **1** shows the Main Distribution Frame and in the background the Intermediate Distribution Frame, with a four vertical uniselector Trunk Distribution Frame standing in front. The racks between the Intermediate Distribution Frame and the Trunk Distribution Frame carry the subscribers' uniselectors, and those in the foreground the " A " digit and 1st code selectors.

The method of supporting the racks by means of transverse channel sections running the full length of the room will be noted, also the flexible method employed of " 'U " bolt fixing, by which means the tops of the racks can be attached to the transverse members in any positions required.

The small number of ceiling fixtures is also apparent, and this forms an important feature since the decision has been made to complete all interior decoration prior to the commencement of an installation.

Fig. **3** should be compared with Fig. **1**, and is included to show the similarity of all racks.

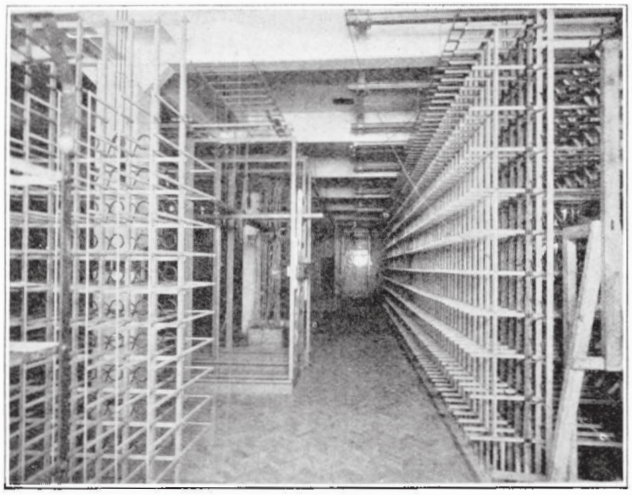


FIG. **7**.

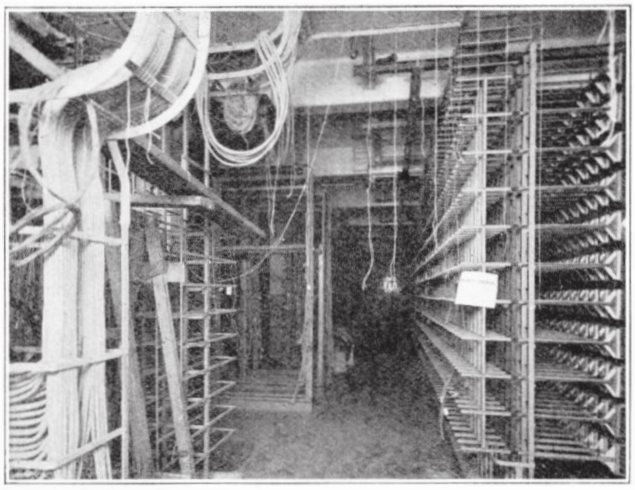


FIG. **8**.

Reading from the front these are the C.C.I. and Coder racks, Miscellaneous Relay Set-racks, 1st and 2nd Numerical Selector racks, and in the background the Final Selector Racks.

Fig. **5** indicates more clearly the arrangement of racks and gangways, and the value of the transverse channel members for supporting cable runways is also apparent.

Fig. **7** shows the Main Distribution Frame and Intermediate Distribution Frame taken from the opposite end of the room to Fig. **1**, and is included as a matter of general interest. Its value will be more apparent in later photographs.

Figs. **2**, **4**, **6** and **8** are taken from similar positions to Figs. **1**, **3**, **5** and **7** and represent the second stage of the installation; this stage constituting the process of cable running.

Fig. **9** shows a typical view of a wiring gangway after the cables have been run in and prior to their being laced to the rack cable supports, and it will not need a lot of imagination to appreciate how the work of running these cables has been simplified by the absence of shelves and apparatus.

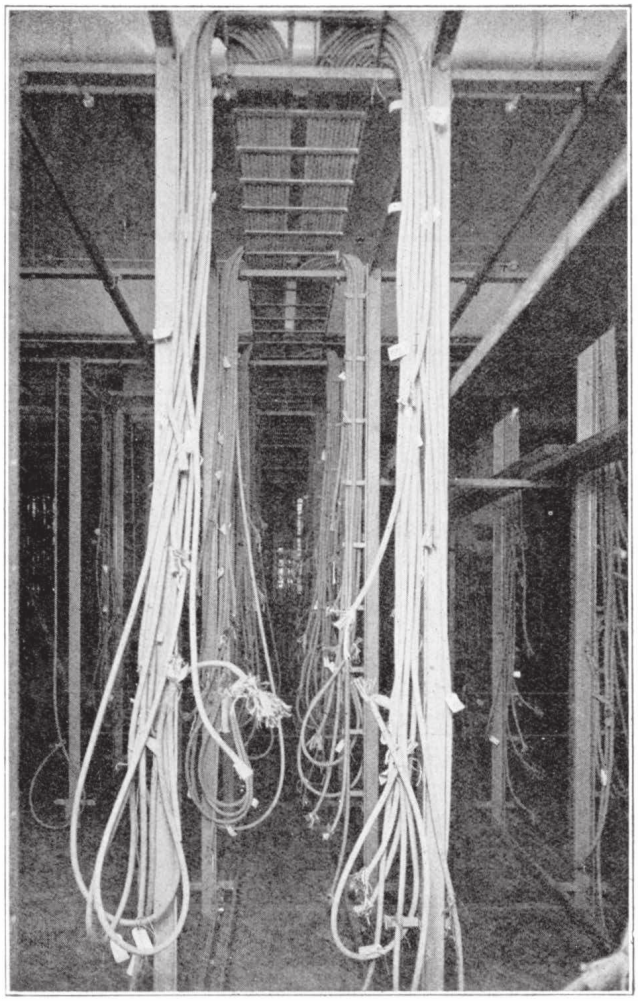


FIG. **9**.

An additional use for the transverse channel members will also be noted. Here they are seen acting as travelling ladder overhead track supports.

Fig. **10** shows how the Intermediate Distribution Frame footings have been treated to eliminate the possibility of dust collecting between the horizontal foot members. The Frame is erected on a strip of ruberoid felt which is surrounded by a wooden curb. The space inside the curb is then filled in with cement, which is prevented from damaging the wooden blocks by the presence of the ruberoid.

The comparative advantages of the new system considered from all aspects, embracing cabling, power distribution, supervision and general maintenance, will be appreciated. The racks are arranged back to back with 1′ 8″ between wiring sides and 2′ 6″ between apparatus sides.

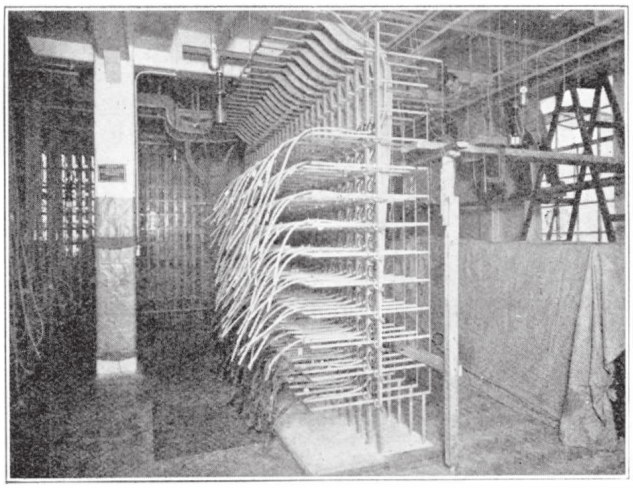


FIG. **10**.

Lighting.—It will be observed that the Exchange is lit throughout by means of standard hanging lamps, necessitating the provision of inspection lamps. A scheme of flood lighting, however, is being prepared by the Engineer-in-Chief's Office for introduction into this Exchange, and will be shown up in the final series of photographs.

Conclusion.—In concluding this—the first of a series of articles dealing with the progressive installation of Acorn Exchange, thanks are due to Messrs. A. B. Eason and G. Brown, of the Engineer-in-Chief's Office, for their considerate co-operation at all stages of the development.

INTRODUCTION OF AUTOMATIC TELEPHONE SYSTEM AT NEWCASTLE-ON-TYNE.

W. A. STRADLING and H. SADLER.

ON the 31st January, 1931, the greater part of the Newcastle-on-Tyne area was converted to automatic working, and this transfer ranks as the largest individual operation of the kind yet undertaken in this country. A total of 10,600 existing subscribers' lines, together with 679 junctions were transferred at midnight from 13 Manual Exchanges of various types to the 12 new Automatic Exchanges installed by Messrs. Standard Telephones & Cables, Ltd. Particulars of the old and new Exchanges, together with those which are to be converted at a later date are given below:—

Exchange.	Type of Manual Equipment.	No. of Existing Lines.	Date of conversion.	Exchange Replacing Old Exchange.	Multiple Capacity of Auto Equipment.	
					Initial.	Ultimate.
Central	Magneto	4400	31-1-31	Central	8800	16000
Central Relief	CB.1	2548	,,	East	1600	4700
City	CB.1		,,	West	1600	4500
Gateshead	Magneto	775	,,	Gateshead	1500	4500
Gosforth	,,	1199	,,	Gosforth	1700	4400
Gosforth Relief	,,		,,			
Felling	CBS.1	150	,,	Felling	300	900
Low Fell	Magneto	350	,,	Low Fell	1000	3400
Jarrow	CBS.1	256	,,	Jarrow	600	1100
Whickham	,,	111	,,	Whickham	200	600
Kenton	Magneto	62	,,	Kenton	100	200
Benton	,,	288	,,	Benton	700	1400
Wallsend	,,	463	,,	Wallsend	900	2800
Total transferred ...		10602	,,	Total	19000	44500
Wideopen	CBS.2.	80	Not fixed.		—	—
Lemington	CBS.1.	150	,,	—	—	—
Jesmond	CB.1	1430	,,	—	—	—
Dunston	CBS.2.	160	,,	—	—	—
Hebburn	CBS.1.	130	,,	—	—	—
Blaydon	CBS.2.	150	,,	—	—	—

As the new equipment is of the well known Strowger type used in all recent installations for the British Post Office, it is unnecessary to give any detailed particulars, but a brief description of certain general features of the scheme will no doubt be of interest. The disposition of Exchanges in the Automatic Area is shown in Fig. **1**.

In preparation for the transfer all subscribers' circuits in the area were brought through the new Exchanges and tees were made on the Main Distribution Frames. Immediately after the transfer all tees were cut away and temporary jumpers were recovered from the frames, the work being completed by mid-day on Sunday, February 1st. This method of arranging for the transfer of circuits to a new Exchange has much to recommend it in cases where it can be economically adopted, as there are no external tees to be removed with the possibility of temporary interruptions after the change-over. Those who have had experience of fault control during the process of cutting away tees on external plant will appreciate the importance of this consideration.

The Central Automatic Exchange, together with the Manual switchboards for Trunk and Toll and the various auxiliary services, is accommodated at Telephone House, a photograph of which is given in Fig. **2**. This building, which

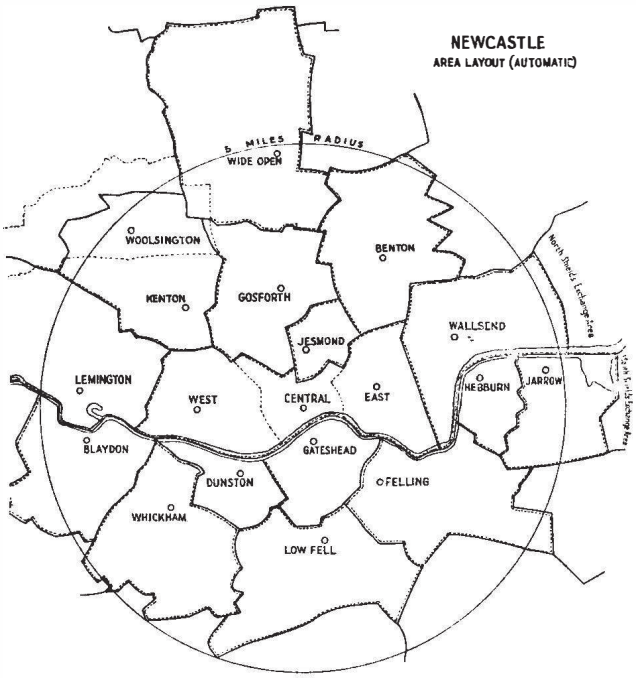


FIG. 1.—NEWCASTLE AUTO. AREA.

presents an imposing appearance, is in Carliol Square and is erected on the site of the old Newcastle Prison. During the excavations for the

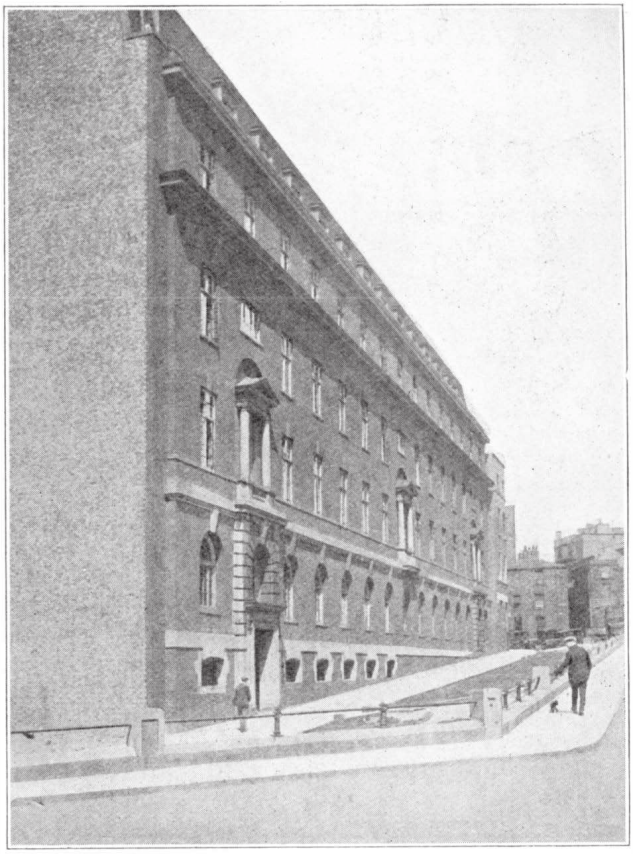


FIG. 2.—TELEPHONE HOUSE, NEWCASTLE-ON-TYNE.

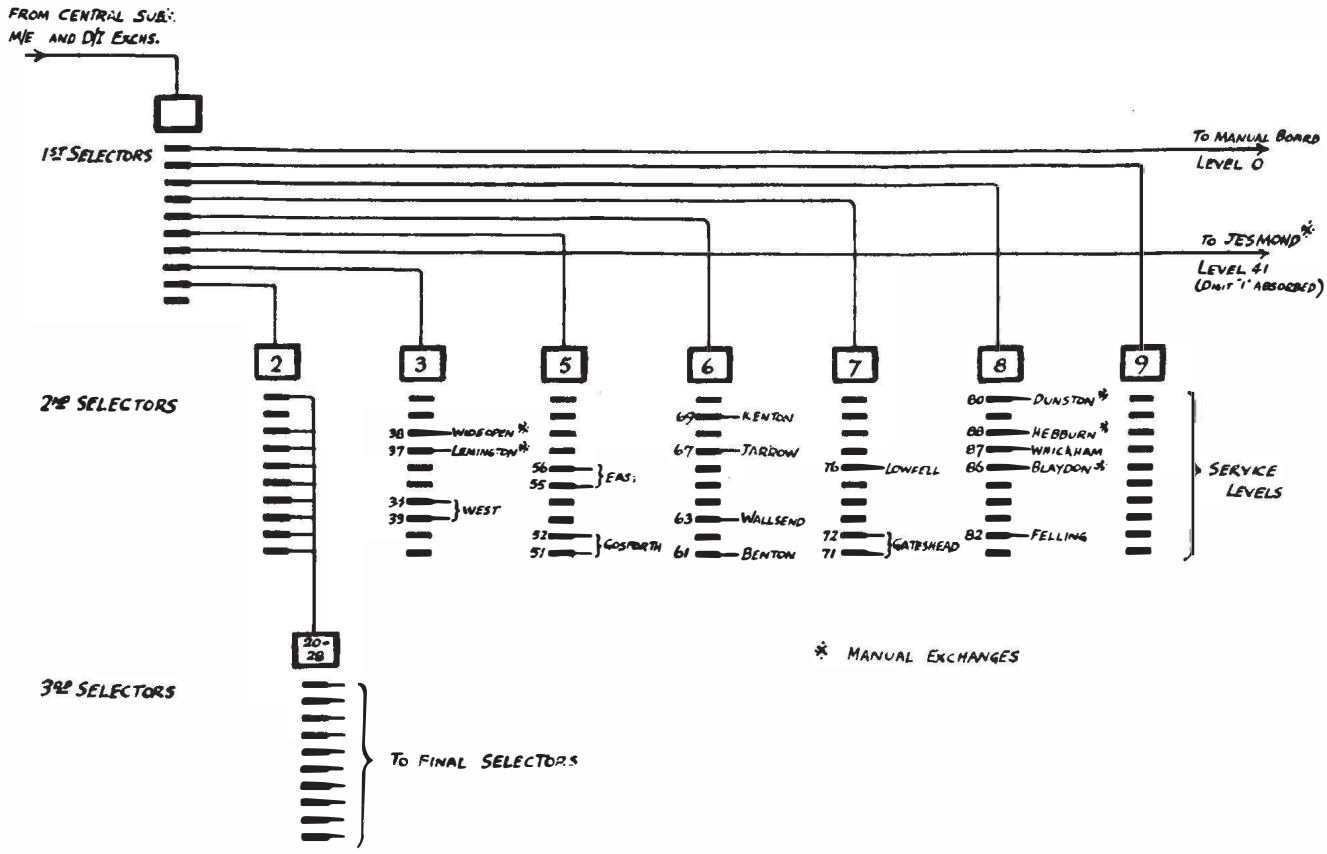


FIG. 3.—TRUNKING SCHEME.

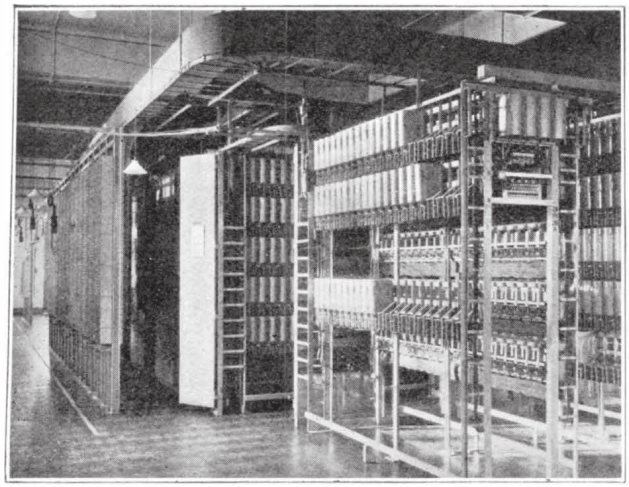


FIG. 4.—NEWCASTLE CENTRAL. TRAFFIC AND SUBS'. METERS ON LEFT. GROUP SELECTOR RACKS.

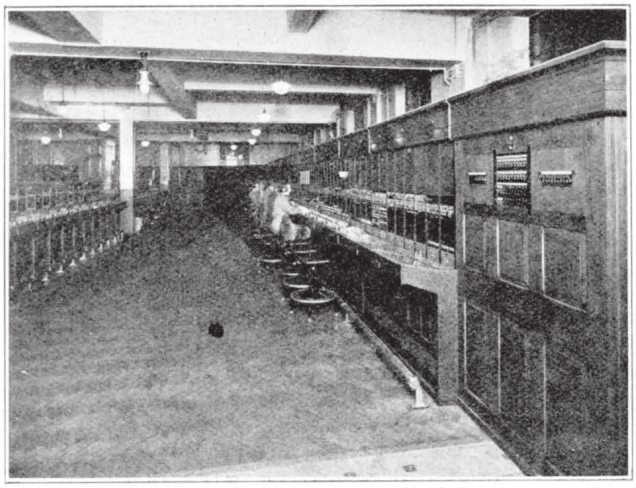


FIG. 6.—NEWCASTLE CENTRAL. MANUAL ROOM. ENQUIRY SUITE ON THE LEFT.

foundations of the new building, the remains of a criminal were found who had been executed and buried in the prison many years ago.

The numbering scheme for Newcastle is on a uniform 5-digit basis for all Exchanges and, with the exception of Jesmond, all exchanges are served from 2nd selector levels at Central; each group of junctions thus serves 1000 subscribers. The scheme is shown in convenient form in Fig. **3**. Provision is made for direct trunking from East and West exchanges to Central subscribers, this plan effecting a considerable economy in junctions and switching plant. Direct automatic junction circuits are also provided between Gateshead and Low Fell.

The Newcastle Trunk Exchange was brought into use on November 15th, 1930, a total of 262 Trunks being transferred from the old Trunk Exchange without trouble of any kind. The Trunk suite consists of four Junction Signalling positions and 24 Generator Signalling positions, together with Trunk Record and Trunk Enquiry Tables. The Auto Manual Switchboard has a

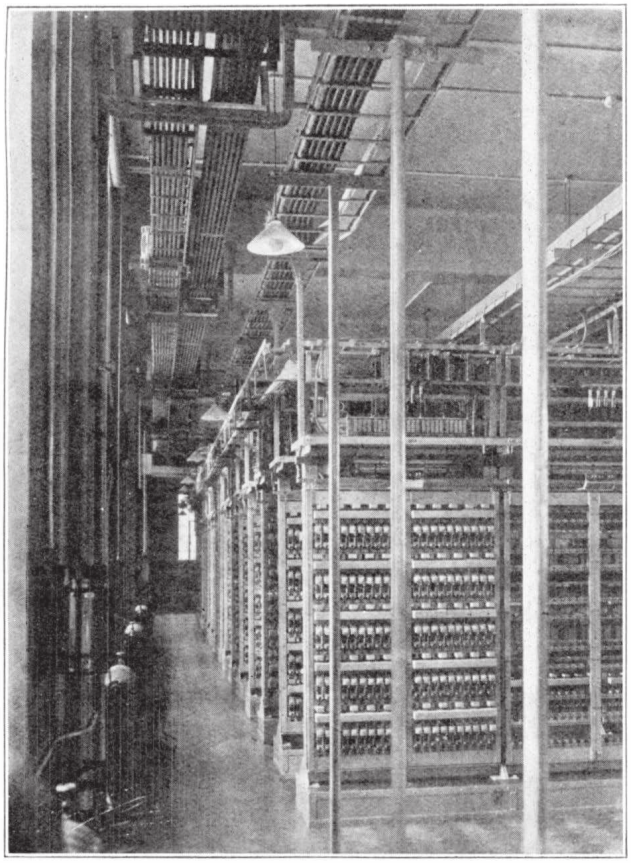


FIG. 5.—NEWCASTLE CENTRAL. LINE AND FINAL UNITS.

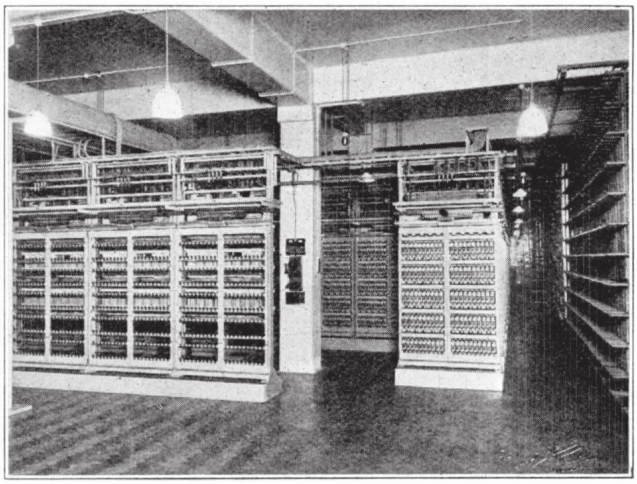


FIG. 7.—NEWCASTLE CENTRAL. LINE AND FINAL UNITS. M.D.F. AND CABLE RUN.

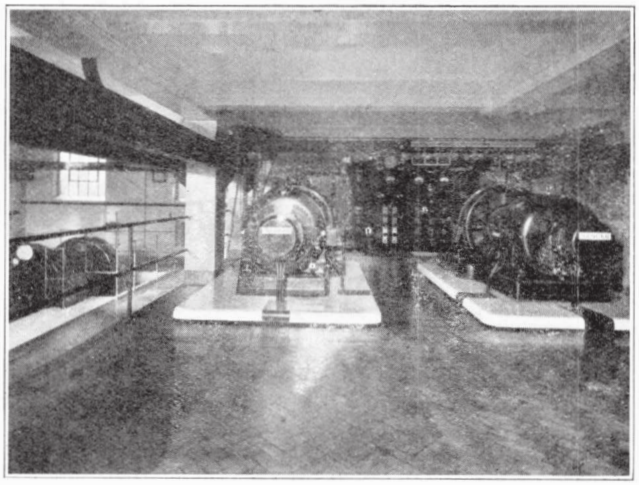


FIG. 8.—NEWCASTLE CENTRAL. CHARGING MOTOR GENERATOR AND POWER BOARD. RESERVE OIL ENGINE EXTREME LEFT.

FIG. 10.—GOSFORTH EXCHANGE.

total of 55 positions, the estimated ultimate requirements being 80 positions.

The Enquiry suite consists of 23 working positions with one unequipped. A special feature of the Enquiry suite is an archway over a break in the section to allow easy access from front to rear without a long detour. The cabling is carried over the gangway and covered with polished mahogany to match the section, an altogether pleasing effect.

The whole of the 4th (top) floor is allocated to Manual switchboard equipment, Enquiry and Trunks. The 3rd flood is occupied by Traffic Staff, Contract Officers, Dining Room and General Welfare accommodation. The 2nd floor is taken up entirely by Automatic Switching Equipment, Main Distributing Frame, Test Desks, etc. The 1st and ground floors are occupied by other Departments, *e.g.*, Board of Trade and Inspectors of Shipping.

The power plant and batteries are located in the basement; the batteries, which were installed by Messrs. The Chloride Electrical Storage Co., Ltd., are of 10,000 ampere hour capacity.

There are three 91 kilowatt generating sets of which two are motor-driven direct-coupled sets and one is an engine-driven emergency set. All three generators were built by the Electrical Construction Co. The emergency generator is driven by a 150 H.P. oil engine of the Ruston vertical type, coupled direct to the main shaft. The oil fuel consumption of this engine is .43 lbs. per brake horse power hour, and the set operates

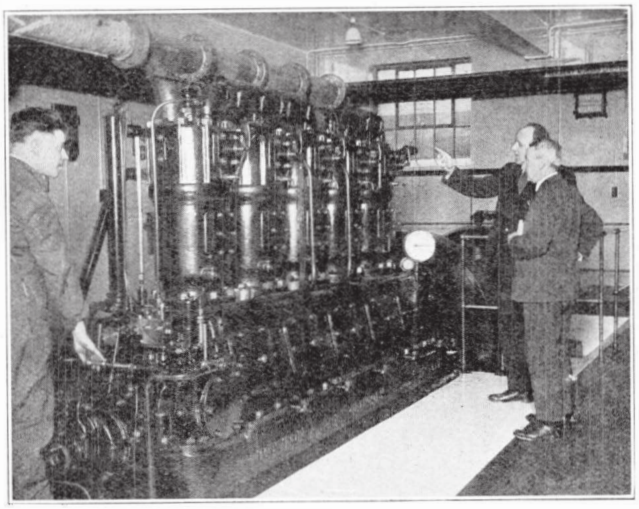


FIG. 9.—NEWCASTLE CENTRAL. RESERVE OIL ENGINE PLANT.

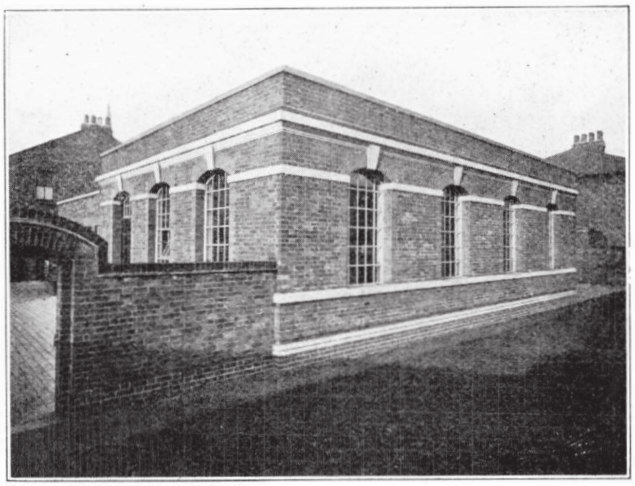


FIG. 11.—JARROW EXCHANGE.

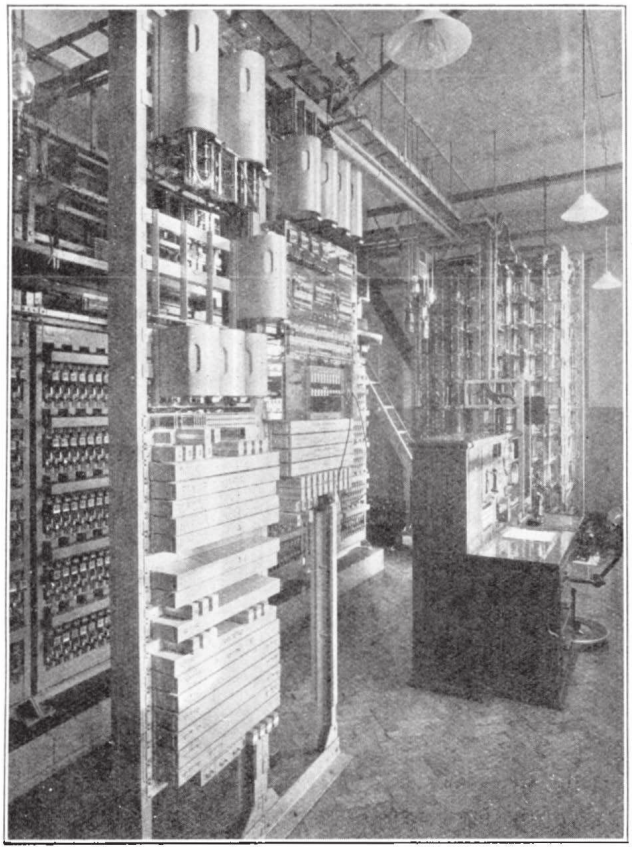


FIG. 12.—JARROW EXCHANGE. SPECIAL APPARATUS RACK, TEST DESK AND M.D.F.

at approximately 80% efficiency at full load. The compressor for this plant is run by a 4 H.P. petrol-paraffin engine capable of working up to full compression in about 20 minutes.

It may be mentioned that the weather conditions prior to and during the main transfer were of the vilest description; heavy falls of snow accompanied by gales of wind and followed by a rapid thaw had their inevitable effect on all open line work in the District. Consequently no new records could be created as regards the absence of faults, notwithstanding the most careful and efficient preparations which had been made by the local staff. In the circumstances, a total of about 250 faults, the majority of which were due to the bad weather conditions, must be regarded as highly satisfactory. Immediately the cut-over had been effected, the work of repairing the effects of the storm was undertaken

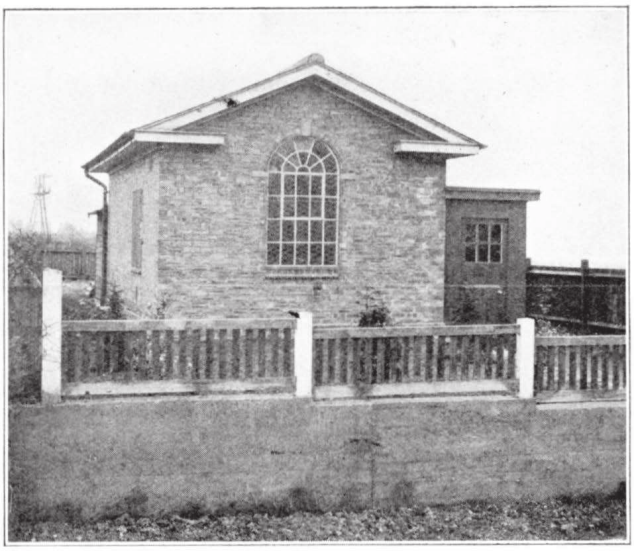


FIG. 13.—KENTON EXCHANGE.

and normal conditions were restored within a remarkably short time.

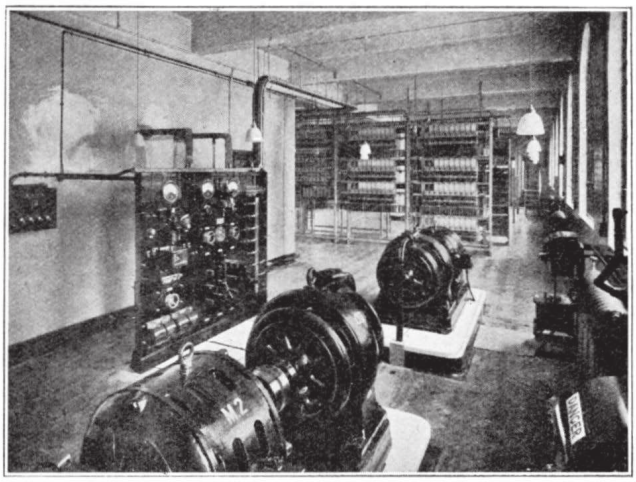


FIG. 14.—EAST EXCHANGE. CHARGING MOTOR GENERATOR, POWER BOARD AND SELECTOR RACKS.

Thanks are due to Mr. F. G. C. Baldwin, M.I.E.E., Superintending Engineer in charge of the District and other local officers, also to Messrs. The Standard Telephones & Cables, Ltd., and the Newcastle Chronicle, Ltd., for information and photographs used in this article.

For a description of the opening ceremony see page 75.

FREQUENCY CHARACTERISTICS OF STANDARD REFERENCE TYYE CONDENSER TRANSMITTERS AND MOVING COIL RECEIVERS.

W. WEST, B.A., A.M.I.E.E.

SUMMARY.—The frequency characteristics are found to depend, both in shape and level on the acoustical conditions under which the calibrations are made. If these conditions are reasonably similar to those of the Standard Reference method of calibration, the results, based on the use of the Rayleigh Disc, are very similar to those obtained by the Thermophone. When, however, actual use conditions are imitated, differences of the order of 5:1 for the transmitters and 3:1 for the receivers are found at certain considerable portions of the frequency range.

1. Some electro-acoustical instruments of the type used in the Standard Reference circuit of Telephone Transmission (at the S.F.E.R.T. laboratory at Paris) have been procured by the Research Section, and it is thought that the results of the calibrations of these instruments may be of interest to telephone engineers. Frequency-characteristic charts were supplied with each instrument and the tests to be described therefore serve a two-fold purpose. In the first place, they provide an opportunity for comparing the absolute measurements, based on a thermophone calibration, with those of the Post Office, which depend on the use of the Rayleigh disc. For this comparison it is necessary to imitate as far as possible the acoustical conditions under which the tests by the former method are carried out. Secondly, it is desirable to measure the performance of the instruments under conditions approximating to those of use.

The condenser transmitters (type No. D85880) differ somewhat from the earlier type (370W), tests on which are described in references 1 and 6. The sensitivity is greater and the depth of the diaphragm recess is less, but the frequency of mechanical resonance of the diaphragm has been reduced. The receivers (type No. D87860) operate by means of a moving coil in a permanent magnetic field, the general arrangement being similar to that of the Wente and Thuras moving-coil unit (reference 2). It will be sufficient to record the results of measurements on one instrument of each type; very similar results have been obtained on other instruments of the same type.

2. *Condenser Transmitter No. 4600.*—The methods of calibration of transmitters by means of the Rayleigh disc have been discussed elsewhere (reference 5). Two methods are used, both of which measure the sensitivity in terms of the voltage output from the transmitter per unit of applied sound pressure, but while the spherical wave method refers to the free air sound pressure, the stationary wave method refers to the actual pressure on the diaghragm. It is this latter notation which is also used in the thermophone calibration. The results of measurements of the performance of instrument No. 4600 are reproduced in Fig. 1, wherein

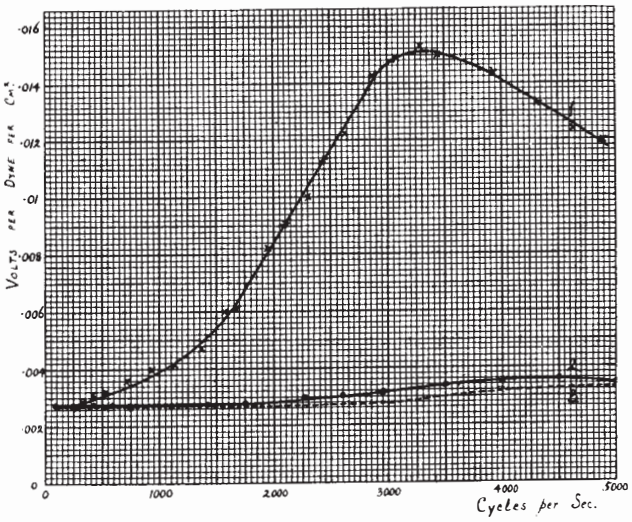


FIG. 1.

curve 1 shows the spherical wave calibration (in terms of free air pressures), curve 2 the stationary wave calibration, and curve 3 the maker's calibration, by thermophone (both in terms of pressures on the diaphragm). In each test the transmitter was polarised with 200 volts.

3. *Receiver No. 20A.*—The calibration of a Standard Reference receiver in the Paris laboratory makes use of an "acoustic coupler" inserted between the receiver and a transmitter which has been calibrated by thermophone.

This comprises essentially a seating fitting on the face of the transmitter and extending the depth of the diaphragm recess by about 0.5 cm. The receiver fits on and the enclosed space is filled with hydrogen at atmospheric pressure. The excitation of the receiver at different frequencies creates pressures in the hydrogen which are measured by the condenser transmitter. The ear-cap of this type of receiver differs from the Post Office receiver cap; it is coned outwards, from an aperture of 2.54 cm. diameter, at a plane angle of 34° to the face of the receiver and rounded off on a diameter of about 4.76 cm. When the receiver is mounted on the coupler for calibration the space included between the aperture of the receiver cap and the diaphragm of the transmitter is about 27 c.c.

The method used by the Post Office for calibrating telephone receivers employs an artificial ear (reference 4) which is calibrated against a Rayleigh disc by the stationary wave method. Receiver No. 20A was first tested on the artificial ear; owing to the size of the aperture of the ear-cap the usual seating could not be used and a plasticine rim was provided instead. The enclosed volume in the cup of the artificial ear, measured from the aperture of the receiver cap, was about 3.5 c.c. and the calibration under this condition is shown in curve 1 of Fig. **2**. When

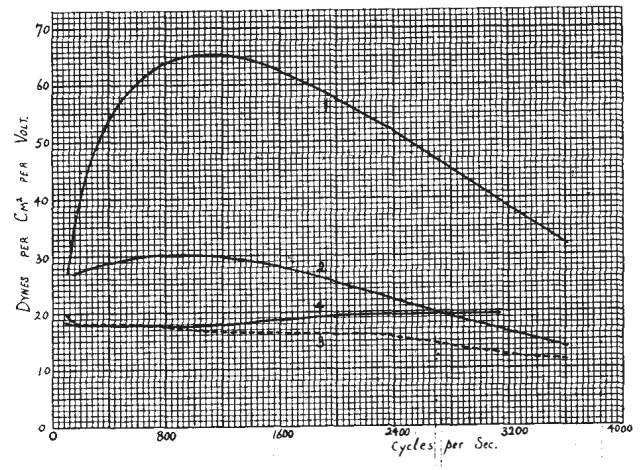


FIG. 2.

the volume was increased to about 9 c.c., curve 2 of Fig. **2** was obtained. Curve 3 shows the maker's calibration of this receiver by the method outlined above, and for curve 4 similar conditions of test were used as follows: An ebonite ring 0.5 cm. thick, having the same internal diameter as the diaphragm recess, was mounted on the condenser transmitter, and the receiver rested on this ring. An almost complete air seal was ensured by a light smear of vaseline over the lower surface and most of the upper surface of the ring—a small part was left unsmeared to permit sufficient leakage to ensure atmospheric pressure within the cavity. The volume of the cavity was thus approximately the same as that used in the Standard Reference calibration of a receiver, namely, 27 c.c., but the content was air and not hydrogen. The thermophone calibration of the transmitter was used to obtain curve 4, since this had also been used for curve 3.

The effective volume of cavity when the receiver is held to an ear was found for an ear-cap of this shape by making a similar cap to fit on to a Bell telephone receiver. The frequency of resonance of the diaphragm was observed when the receiver was held to the ear and also when it was closed with a known and adjustable volume. Observations on twelve ears showed a mean volume of 4 c.c., the extremes ranging from 2.4 to 5.4 c.c., at a frequency of about 1200 cycles per second. It appears therefore that the conditions under which curve 1 of Fig. **2** was obtained closely approximate to the actual conditions of use on the ear.

4. *Comment.*—These measurements show that considerable differences in sensitivity are to be expected according to the conditions under which the instruments are tested. Compare first curves 2 and 3 of Fig. **1**; in both of these the sound pressures measured are those at the surface of the diaphragm, and the agreement is, on the whole, very close. The Rayleigh disc calibration (curve 2) indicates, however, a somewhat lower frequency of maximum sensitivity than the Thermophone calibration (curve 3). This may possibly be due to the difference in conditions under which the tests are made; for the Rayleigh disc test the acoustical impedance at the diaphragm is non-reactive, while for the Thermophone test there is a considerable elastic reactance due to the volume of 9.1 c.c. of hydrogen in the thermophone chamber. The removal of this reactance would tend to reduce the total effective stiffness of the diaphragm and therefore to lower its frequency of mechanical resonance. The mechanical resistance due to

the air in front of the diaphragm is probably large, in both tests, as compared with the condition of free air.

When the transmitter is calibrated as an instrument for measuring free air pressures, as in curve 1 of Fig. **1**, the differences are very much greater. Two effects involved here have been discussed in detail elsewhere,* namely, the augmentation of sound pressure due to obstruction of the sound wave and due to concavity in the face of the instrument. For these transmitters the effects of mechanical resonance also appear within the frequency range, and, as stated above, it is to be expected that the frequency of mechanical resonance will be reduced by the removal of the elastic constraint of the thermophone chamber. The maximum amplitude of displacement of the diaphragm will therefore be increased—an effect which will be still more pronounced if the reduction of the mechanical resistance is also appreciable. It is the free air condition of test that most nearly represents the circumstances under which the transmitter is generally used.

The characteristics of the moving coil receiver, shown in Fig. **2**, are seen to depend fairly critically on the volume of the cavity to which it is exposed under test. If a source of sound whose strength is U, defined as the rate of volume displacement, operates on an acoustical impedance Z, the pressure developed is, by definition of the acoustical impedance, $p = Z.U$. Hence, if the strength of the source is not appreciably affected by a change in the impedance, the pressure is directly proportional to the impedance. If the impedance is that of the air in a small confined space, *i.e.*, if the wave-length is large as compared with any linear dimension of the space, this pressure will be the same over the whole of the enclosing surface. In the Appendix it is shown that this impedance can be expressed in terms of the volume Q of the space and of the absorption of sound at the enclosing surface, in terms of that due solely to an ideal tube of infinite extent (or terminated by its own impedance) whose cross sectional area is σ.

Thus the impedance

$$Z = \rho c \left[\frac{\sigma - j(kQ)}{\sigma^2 + (kQ)^2} \right]$$

where ρ = density of air, c = velocity of sound in air $k = \frac{\omega}{c}$ and $j = \sqrt{-1}$. The modulus of the impedance is

$$(\text{Mod})\ Z = \frac{\rho c}{\sqrt{\sigma^2 + (kQ)^2}}.$$

Consideration of this expression shows that at frequencies where kQ is large as compared with σ, for any given frequency the impedance is inversely proportional to Q, but at lower frequencies the term σ reduces the effect due to a change of volume. The values of Q and σ are known for the conditions under which curves 1 and 2 of Fig. **2** were obtained; σ for the artificial ear is about 0.38 cm^2 and Q_1 and Q_2 were about 3.5 and 9.0 cm^3 respectively. The ratio of the calculated impedances of the cavities used for curves 1 and 2 are compared with the ratio of the ordinates of these curves in the following table:—

Frequency Cycles per Sec.	Calculated Impedance ratio.	Observed Pressure ratio.
100	1.08	—
200	1.25	1.44
500	1.82	1.95
1000	2.25	2.2
2000	2.47	2.3

The volumes were not measured to a high degree of accuracy and the change of impedance as between curves 1 and 2 may be sufficient to affect the strength of the source of sound. The agreement is, however, sufficiently close to show that the observed differences are such as might be expected from purely acoustical considerations.

A comparison between curves 3 and 4 of Fig. **2** indicates that at the lower frequencies there is no appreciable difference betwen calibrations made with different, coupling devices enclosing the same volume. For these tests the resistance component is small and the term σ may be neglected at all except perhaps very low frequencies, so that the acoustical impedance reduces to $\frac{\rho c^2}{\omega Q}$ and the value of ρc^2 is substantially the same for air as for hydrogen. At frequencies higher than 1000 cycles per sec. there is diver-

* *References 1, 5, 6 and 7.*

gence, due probably to the fact that with the shorter wave-lengths in air the pressure becomes less uniform throughout the chamber, which is comparatively large.

Appendix.

The Acoustical Impedance of Air in a Small Confined Space.

An expression for the acoustical impedance of air in a confined space, whose linear dimensions are small as compared with a wave-length, may be obtained from first principles so that the applicable simplifying approximations may be expressly stated. It is shown in Appendix I. of reference 3 that the acoustical impedance of a tube whose cross-sectional area is S and whose length x is terminated by a plug having reflection factor g is

$$Z = \frac{\rho c}{S}\left[\frac{1 - g^2 - j \cdot 2g \sin 2kx}{1 + g^2 - 2g \cos 2kx}\right] \quad \ldots\ldots(1)$$

If x is small, the interior of the tube is a small confined space and, approximately, $\sin 2kx = 2kx$ and $\cos 2kx = 1 - 2(kx)^2$. Also when g is nearly equal to unity $4g = (1 + g)^2$, approximately; the error is in fact less than 1.5% when g is as small as 0.8. In the present case this approximation is admissible since a small value of g means that a large proportion of the sound is emitted as a progressive wave, which is not consistent with the idea of sound pressure developed in a confined space. With these assumptions then equation (1) may be rewritten as

$$Z = \rho c\left[\frac{S\left(\frac{1 - g}{1 + g}\right) - jkxS}{S^2\left(\frac{1 - g}{1 + g}\right)^2 + (kxS)^2}\right] \quad \ldots\ldots(2)$$

As has been shown in the reference cited above, the acoustical resistance due to absorption of sound at the end of the tube is $\frac{\rho c}{S}\left(\frac{1 + g}{1 - g}\right)$. This expression may more conveniently be expressed in terms of the cross-sectional area σ of an ideal tube in which viscous effects are absent and which extends to infinity from an otherwise rigid wall. The acoustcal resistance of this termination to the tube whose area is S is $\frac{\rho c}{\sigma}$, whence $S\left(\frac{1 - g}{1 + g}\right) = \sigma$. The product $x \cdot S$ is the volume Q of the enclosed space, hence

$$Z = \rho c\left[\frac{\sigma - j(kQ)}{\sigma^2 + (kQ)^2}\right] \quad \ldots\ldots(3)$$

This expression is analogous to that for the electrical impedance of a capacity in parallel with a resistance. It has been calculated for a cavity of cylindrical shape; it applies, however, to any other shape provided that the pressure is uniform throughout the cavity.

References.

1. *A. J. Aldridge. Journal P.O.E.E., 1928, Vol. 21, p. 223.*
2. *E. C. Wente and A. L. Thuras. Bell System Technical Journal, 1928, Vol. 7, p. 140.*
3. *W. West. Journal P.O.E.E., 1929, Vol. 21, p. 293.*
4. *W. West. Ibid, 1930, Vol. 22, p. 260.*
5. *W. West. Journal I.E.E., 1929. Vol. 67, p. 1137.*
6. *W. West. Ibid, 1930, Vol. 68, p. 441.*
7. *S. Ballatine. Proc. Inst. Radio Engineers. Vol. 18, No. 7, p. 1206.*

THE TELEPHONE INSTRUMENT EFFICIENCY TESTER.

A. HUDSON, B.Sc., A.C.G.I.F.C., A.M.I.E.E.

INTRODUCTION.—In an article in this Journal for October, 1929, entitled "The Mechanical Testing of Transmitters and Receivers," a description of a new method of testing subscribers' instruments in bulk is given. This method involves the use of a rhythmic type of oscillator and a special amplifier-rectifier, the characteristics of which are fully described in that article.

It is of interest to recall that the idea of utilizing a rhythmic oscillation principle as a substitute for speech in transmission measurements originated in the Post Office Research Section in 1915. (See I.P.O.E.E. Professional Paper No. 70, 1916). It is understood that the idea was adopted in America and is now in extensive use in the Bell System as a substitute for the voice.

Since the date of that article a set has been constructed for the purpose of testing the new microtelephones at the contractor's works. These instruments, owing to their peculiar characteristics, are very difficult to test by the ordinary speech methods. Factors such as side tone and the size of the observers' heads preclude the possibility of an accurate test, unless a large number of tests with several observers are made on each instrument. The "T.I.T." by providing a simple means of standardising the conditions of test enables an accurate test to be made much more quickly, a correction factor being applied to the results to allow for the difference between the two methods of test.

This set which was the first attempt to put the method into practical use has facilitated the collection of a considerable amount of data on the behaviour of a set of this kind under service conditions. The troubles inseparable from a new test in its early stages have proved of considerable value when the question of designing a set suitable for Test Section use was considered.

The experimental set is mounted on two racks, each about 16 inches high, which stand on a bench close to the actual testing bench. One rack contains the oscillator circuit, while the other has the amplifier-rectifier and control gear on it. All necessary switching is carried out by means of lever keys which are conveniently placed underneath the meter. It was found, after the installation of the set, that facilities additional to those provided were required and the keys necessary for these purposes are mounted external to the set. The oscillator feeds a loud speaker when testing transmitters and a dummy ear when testing receivers. The dummy ear which was used with the experimental set has given considerable trouble when used continuously, as it varies considerably in efficiency from day to day. This is probably due to the fact that the necessary damping is obtained from a receiver diaphragm. In the new type, which is being used in the new sets, the damping is obtained by air friction and there are no moving parts; so that this difficulty does not arise.

A maintenance scheme has been introduced and will probably be continued when the new sets are brought into use. A difficulty experienced with the staffing of the set is due to the fact that the men are only at the works for three months at one time, and it is not satisfactory for a continual succession of new men to undertake the maintenance of the set. It has been found advisable to train one man to do the necessary maintenance work, while the operator concerns himself only with the working of the set. This arrangement has other advantages, because the relieving of the operators can be effected without stopping the set while a new man is being taught. The maintenance officer attends to all records and to the weekly valve checks. The valve checks are carried out by means of a valve tester of a type which tests the valve in its working circuit, so that in the event of a fault occurring, there is a record of what the valves should do and the localisation of a fault is made comparatively simple. The valve test figures are returned to headquarters and form a useful record of the state of the set at any one time.

The chief faults which have occurred up to date have been found to be due to wear in apparatus, such as the rotary condenser, change-over keys and valves. The latter have given a con-

siderable amount of trouble as, owing to the fact that they are on continuously for about 8 hours a day, only a valve with an exceptionally long life can be relied upon to be stable for any length of time.

Description of the new type sets.—Experience with the first set has shown that in spite of its imperfections, considerable improvements in both speed and accuracy are obtained and it has been decided to equip the Test Section at Studd Street and Birmingham with sets which would embody the experience gained with the first one, with the addition of apparatus and facilities which have been shown to be desirable.

The lay-out of the new sets has been made quite different from that of the experimental set. All the apparatus has been placed on a standard double-bay apparatus rack, 6 ft. high. Photographs of the front and back views are given in Figs. **1** and **2**. It is found that this method has a big advantage over the bench type set from the points of view of floor space and maintenance. The set is completely self-contained from the operational standpoint, all the controls being concentrated on the control panel, which is immediately above the removable desk.

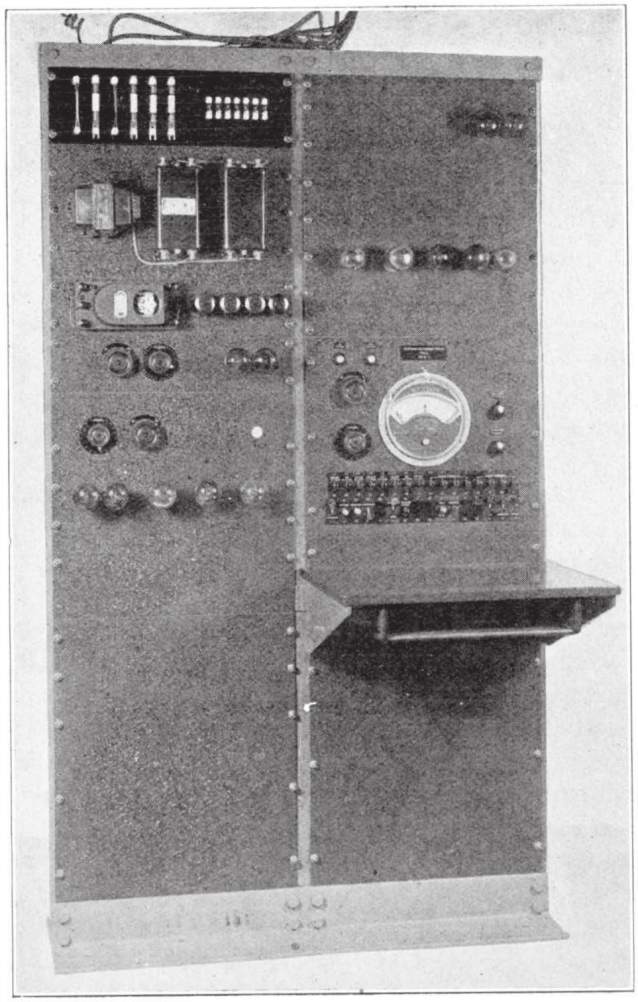


FIG. 1.—TELEPHONE INSTRUMENT EFFICIENCY TESTER. FRONT.

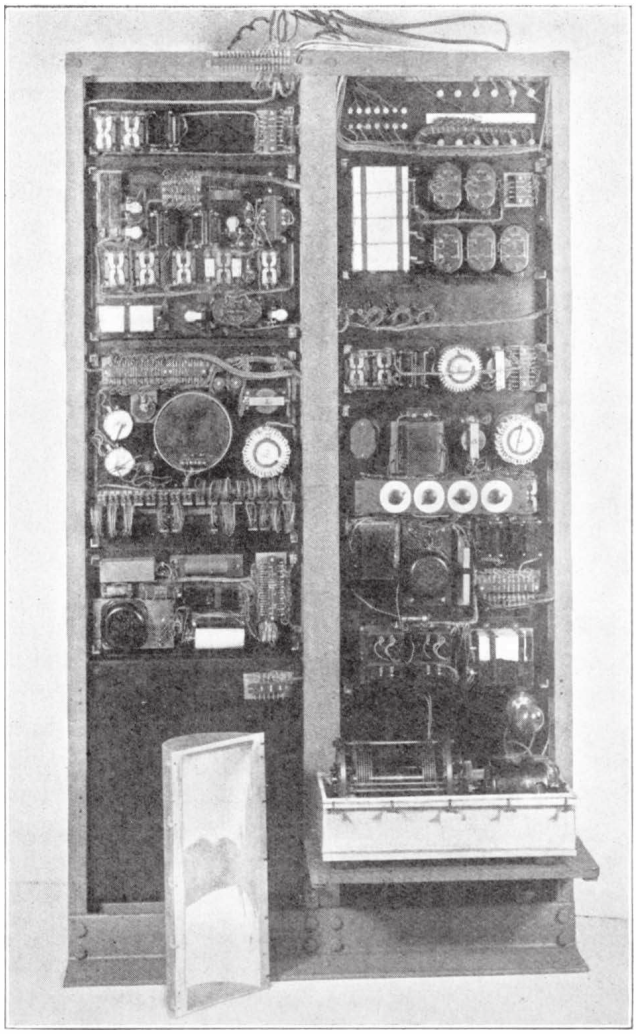


FIG. 2.—TELEPHONE INSTRUMENT EFFICIENCY TESTER. BACK.

In Fig. **1** the left bay is taken up with the oscillator, H.T., and relay panels. The right bay contains the oscillator supplementary amplifier, amplifier-rectifier, control and instruments feeding circuits panels.

The oscillator circuit is so arranged that in the event of more than one set being required at a testing station, one oscillator can be made to serve any number up to ten sets at one time.

This is effected by fitting each operating bay with a supplementary amplifier fed from the main oscillator output. The first two sets fitted would be as shown in the photograph, while the remainder of the sets would consist of single bay racks similar to the right bay. The oscillators are arranged so that either may be used to feed all the sets at once. The advantages to be gained from this arrangement are many. Apart from the saving in cost, which may amount to as much as £1,600 in the case of a full sized installation, freedom from breakdown of the testing arrangements in the event of failure of any part of the apparatus is obtained, and this may be an important factor in a big works producing thousands of pieces of apparatus per week.

Description of Circuit Facilities.—The oscillator circuit, apart from the modifications necessary for multiple working is similar in design to the first set; advantage has been taken of the redesign to obtain a better lay-out and a cleaner wiring run. It has been found possible to control the whole of the setting of the oscillator by means of four potentiometers, which may be seen immediately behind the valveholders. Another potentiometer, not shown in the photograph, is fitted so that a correction may be obtained for the alteration in load caused by an increase in the number of testing sets. A further adjustment of the A.C. supply to the loud speaker is obtained by means of another potentiometer on the input circuit of the supplementary amplifier. This is necessary to compensate for possible losses between the oscillation and the test sets.

The relay panel contains a high resistance moving coil relay connected to the oscillator filament circuit, which, by operating one of two other relays and thence lighting one of two lamps on the control panel, gives a visual signal of the state of the filament voltage. Two other relays are fitted which give remote control of the A.C. and D.C. circuits. The H.T. panel, which is the only other panel on this bay, contains chokes and condensers mounted on the back for smoothing the H.T. supply and separating the H.T. feeds to the oscillator and amplifier-rectifier panels. The transformer and rectifiers to be seen on the front of this panel are only fitted to the set shown here. The H.T. supply for other sets will be derived from motor-generator sets with synchronous motors run from the electric light mains.

The right-hand bay contains the supplementary amplifier, amplifier-rectifier, control and instrument feeding circuits panels, taken in order from top to bottom. The supplementary amplifier panel has already been described. The amplifier-rectifier has been completely redesigned, in order to cater for the new type dummy ear. The specification as regards frequency characteristic has been kept the same (receiver on ear), but the amplification has been increased by the addition of another stage. The balanced rectifier principle, which has proved to be of considerable advantage in the working of the set, has been extended in scope so that the standard settings for receivers and transmitters may be adjusted independently of each other. See diagram in Fig. **3**.

The control panel is so arranged, in conjunction with the feeding circuits panel, that any type transmitter or receiver may be tested on its appropriate circuit; in addition, it is possible to test complete bell sets or subscribers' circuits. This is effected by means of lever type keys, which change over the transmitter, receiver, and line terminals from the standard C.B. conditions to those selected. Two circuits, in addition to the standard C.B. are fitted: standard L.B. and operators'. A blank wooden panel of considerable size is provided with a set of terminals so that any special set-up can be screwed to it and connected to the regular testing equipment. Another key disconnects the standard subscriber's circuit from its local line and brings out the local line to a separate pair of connection clips for the purpose of testing bell sets and a special type of receiver which will be referred to later.

The operational keys are arranged so that, working from left to right, each key must be operated in turn in testing apparatus such as the new microtelephone. This scheme ensures that all the tests required are performed on each instrument. Considerable difficulty has been experienced in carrying out all the switching necessary with only one key operation to each circuit change. The complications arise from the fact that interruptions at two seconds intervals are required when testing transmitters, which are unnecessary when testing receivers.

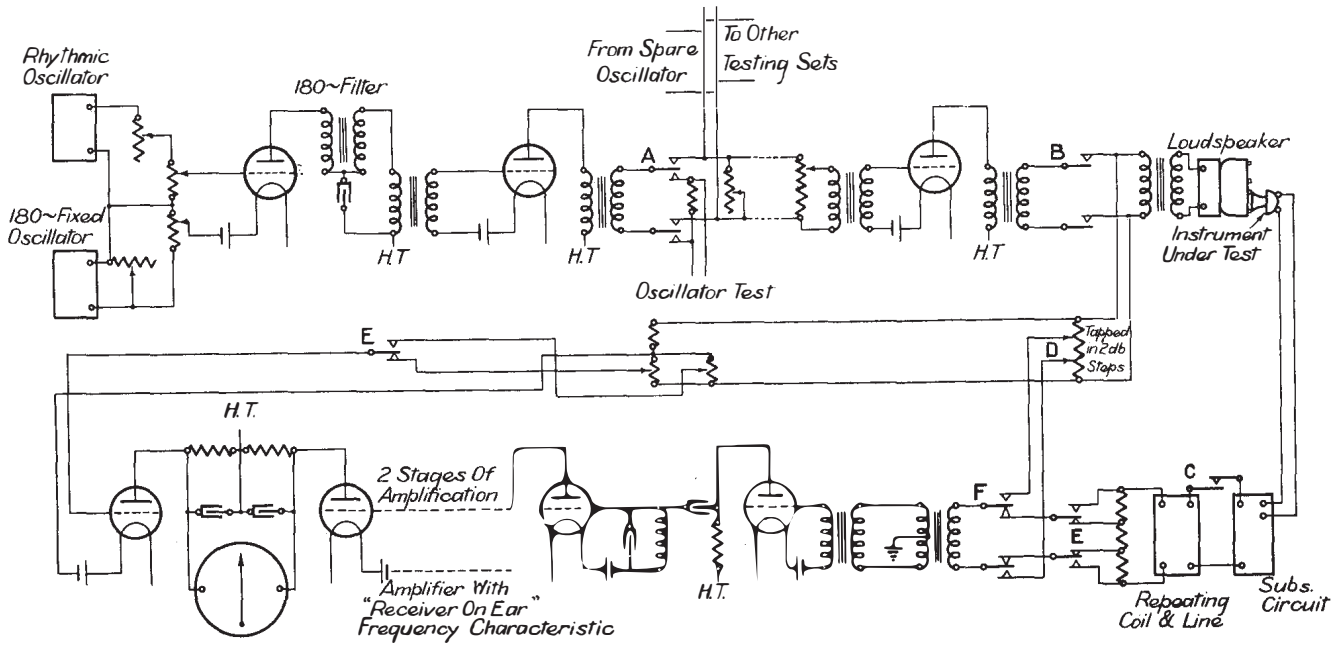


FIG. 3.—TELEPHONE INSTRUMENT EFFICIENCY TESTER. CIRCUIT DIAGRAM.

The testing bench is about 15 ft. long, with the loud speaker fitted in the centre. Connection of the apparatus under test is effected by means of spring clips, one set on either side of the loud speaker. Three boys are sufficient to feed instruments to the set, if a high speed of working is required, but two can work the testing bench with a consequent slowing-up of the speed.

Day to day calibration of the set is made by testing on the set a batch of specially selected and standardised transmitters or receivers in the normal fashion. The figures obtained in this way are corrected by the individual labelled allowances of the standards. The resultant figures give the figure for Department's standard according to each transmitter or receiver. The average of the batch gives a working figure which must then be corrected by the appropriate allowances in order to find the "Working throw-out figure." These calibrations have to be made at least once a day, as it is found that considerable variations may occur from time to time, though if it were found that a set remained constant for a considerable time the interval between calibrations could be increased. In the case of the experimental set, variations of the order of two db. have occurred during periods of about a week, and consequently frequent calibrations are necessary to ensure that a change is corrected before it can affect the level of acceptance.

The exact cause of these variations has not yet been discovered, as there is at present no suitable substitute for the carbon transmitter to enable a direct check to be made. Examination of the calibration figures show appreciable variations in the individual figures, so that some part at any rate of the trouble must be due to the standard apparatus.

Attempts have been made to reduce the possibility of set variation by gradually eliminating all apparatus which could possibly give rise to trouble in this connection. The set is self-checking within fairly wide limits, so that the only apparatus which, by changing its allowance, can affect the calibration of the set is the loud speaker or the dummy ear. The first is a moving coil loud speaker of well known make which is of extremely simple design and excellent

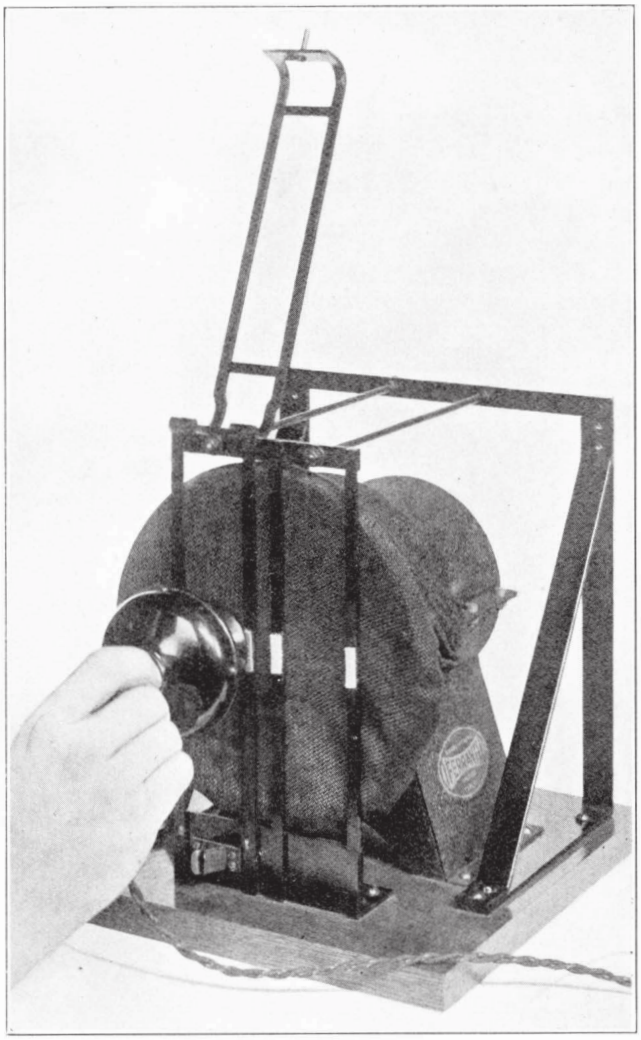


FIG. 4.—PICKING UP ENERGY FROM LOUD SPEAKER. NOTE DISTANCE GUARDS.

construction; the latter is made with no moving parts so that temperature changes and other effects will not alter its efficiency. Some trouble was experienced in the early stages due to a difficulty in applying the receiver to the device. This has now been overcome by a spring clip connection with a wide and firm seating for the receiver cap.

Use of the new sets has led to a considerable economy in time and ensures that more stable apparatus is selected as standards, because larger numbers of instruments may be tested at one time, ensuring continuity in the tests. The method actually in use is to test a batch of about 250 transmitters or receivers, either twice or three times a week, until eight or nine tests have been made on each. Those which show a variation of more than, say, 1.5 db., are discarded and the remainder are then set aside to form a stock from which standards are drawn as required to be finally calibrated, either by the speech methods, or on the T.I.T. to form T.I.T. standards.

A new method of calibration is being developed which, it is hoped, will take the place of separate calibration by receiver and transmitter. The iron-cased electromagnetic receiver which is used in connection with the testing of apparatus at the subscriber's office is being improved with the object of reducing the inherent variability to a figure much below that of either normal transmitters or receivers. It will be possible to give a figure for this receiver in terms of both the Department's standards.

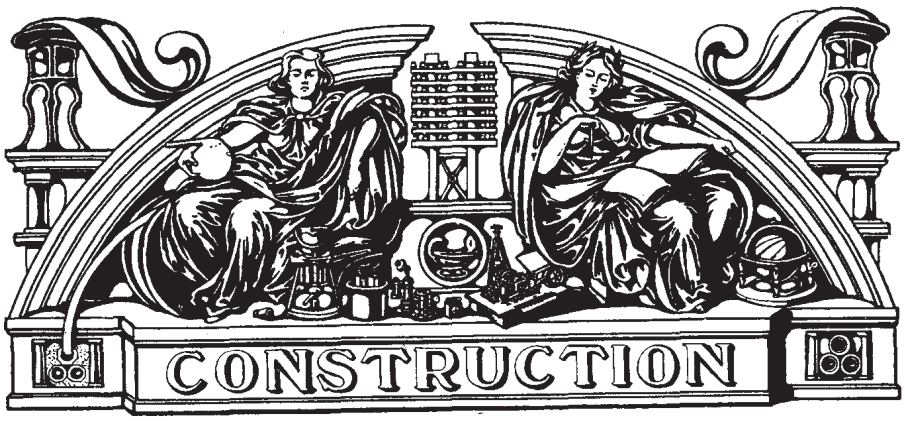
Future Developments.—The new type of set has been found to be quite satisfactory for the purpose for which it was designed, *i.e.*, the rapid testing of apparatus at contractors' works. The speeds obtained have been found to be higher than those hoped for. The new microtelephones have been tested at the rate of 86 an hour. Assuming that after warming up the set and calibrating it, there are six working hours a day (the minimum), about 500 instruments would be tested per day, each involving two tests. Even though two men are used at present in running the set, this is still more than twice the output per man by the old speech methods, while the figures are much more definite. Where multiple set working is found to be necessary the output per man will be much higher, because one man can maintain all the sets, so that his time would be split up amongst several sets instead of being charged to one only.

The use of this tester has been called for in the specification for Telephones Nos. 162 as the method that will be used in testing that apparatus, and it is proposed to extend it later for general use at contractors' works. A scheme for controlling the calibration of the sets has already been worked out for inclusion in the latest pattern. A db. attenuator is fitted which can be used to check the calibration of the meter, as it gives 2 db. steps over a range of 16 db. A scrutiny of the calibration figures week by week enables a running check to be kept on the working of the set, while the maintenance methods already described ensure that any fault is dealt

with before it can have any effect on the supplies.

A considerable amount of research is still required in order to extend the scope of the set. Some instruments still give results which do not agree with the figures obtained on a speech test, while receiver testing is found to be uncertain when new types of apparatus are tested. Preliminary tests indicate that this discrepancy is due to the difference in temperature between the speech and T.I.T. conditions of test, although the difficulties of the tests made the results very inconclusive. A comparison of the frequency characteristics of a number of receivers shows that the efficiencies as derived from the area under the curves are much closer to the T.I.T. figures than the corresponding speech figures.

The solution of these and other problems will come with time, but no mechanical apparatus can ever completely take the place of the human voice and ear which are the ultimate referenda as to the quality of transmission.



THE ANGLO-FRENCH (1930) SUBMARINE TELEPHONE CABLE.

F. E. A. MANNING, M.C., B.Sc. (Eng.), A.M.I.E.E.

THE rapid increase in International Telephone Traffic consequent upon the technical development of long-distance communications during the past few years having completely taken up all available circuits, it was found necessary in 1930 to provide additional submarine links between England and the Continent. A description of one such link providing 24 channels has recently been published,* and this article describes another cable which will give a further 21 circuits.

The Anglo-French (1930) submarine cable was manufactured by Messrs. Siemens and Halske, of Berlin, and was laid by the cable ship "Norderney" from Le Portel to Seabrook, a distance of 32.11 nauts. The same firm also provided a land cable of similar nature for the 2.25 nauts between Le Portel and Boulogne Repeater Station. From Canterbury Repeater Station to Seabrook circuits work on the four-wire system in a 104 pair/20 lb. P.C. Quad cable, loaded with 44 mH coils at 2,000 yards spacing, and provided by Messrs. Standard Telephones and Cables, Ltd. The "Go" and "Return" circuits are separated by electrostatic screens of metallised paper. At Seabrook, four-wire/two-wire terminations with all necessary transformers and balances are installed in sheet-iron air-tight cabinets in an unattended cable hut. Two-wire working is adopted between Seabrook and Boulogne Repeater Station.

The submarine and (French) land cables are of the seven-quad, continuously loaded, A.S.P.C. type, made up in star-quad formation and allowing the use of phantom circuits. Quad crossings in the construction of the cable and large unbalances will prevent the use of double and quadruple phantom circuits, owing to high cross-talk between the double phantoms and other circuits forming their limbs.

Constructional details are as follows:—

Conductors. — Solid cylindrical annealed copper wire of 1.8 mm. (0.0709 inch) diameter and weight 22.65 kg. per km. (92.5 lb. per naut).

Loading.—One layer of iron wire of 0.15 mm. (0.0059 inch) diameter.

Dielectric.—Each loaded conductor covered with a helical winding of string and with paper, of uniform thickness not less than 0.065 mm. (0.00256 inch).

Make Up.—Four insulated conductors are stranded in star quad formation, and each quad is wrapped in paper. The cable is stranded with one quad in the centre and six in the outer layer, and the whole is surrounded by two layers of paper and one layer of Hessian tape.

* *"The Anglo-Belgian (1930) Submarine Telephone Cable," by M. E. Tufnail and J. F. Doust. P.O.E.E.J., Vol. 23, Part 4.*

Colour Scheme.—The two wires forming a pair are covered with paper of the same colour, white for the AB pair and red for the CD pair in each quad. The individual wires of each pair have no distinguishing marking. The quad wrapping papers are red, blue, white or green, the make up being as follows:—

Centre: Green.

Outer layer: Blue, white, red, white, red, white.

There is no colour indication of clockwise or counter-clockwise rotation.

Sheathing of Submarine Cable.—The cable is covered with two sheaths of an alloy of lead and tin, containing at least one per cent of tin. Between the two sheaths is a layer of bitumen compound. The mean thickness of each sheath is at least 1.8 mm. (0.0709 inch) and the minimum thickness of any transverse section is not less than 1.7 mm. (0.0669 inch). The external diameter of the outer lead sheath is (about) 32 mm. (1.26 inch).

Armouring of Submarine Cable.—The outer lead sheath is covered with layers of impregnated paper and a layer of tarred jute, of thickness at least one millimetre (0.0394 inch). Over this is placed a spiral armouring of 21 galvanised iron wires of 6 mm. (0.236 inch) diameter with a suitable lay.

The whole is served with a layer of oiled tape and two layers of three ply jute, one coating of bituminous compound being applied over each serving. The two servings of jute are laid on in reverse directions. The bituminous compound consists of 85% tar, 12.5% bitumen and 2.5% resin.

A length of about 10 nauts laid near the French coast, where the bottom of the sea is rocky, has in addition over the double lead sheath a rubber sheath of 2 mm. (0.0787 inch) thickness, to prevent ingress of water should the lead sheaths crack.

Dimensions of Submarine Cable.—

Weight: 10,800 kg. per km. (19.7 tons per naut).

Overall diameter: (about) 56 mm. (2.205 inches).

Manufacturing Lengths.—

Cable core without joints—400 metres (437 yds.).

Continuous lead sheath—800 metres (875 yds.).

Sheathing of Land Portion.—The cable is covered with a single sheath of lead-tin alloy, containing about one per cent. of tin. The mean thickness is at least 2.5 mm. (0.0985 inch) and the minimum thickness of any transverse section is not less than 2.4 m.m. (0.0945 inch).

The external diameter of the lead sheath is (about) 30 mm. (1.18 inch).

Armouring of Land Portion.—The lead sheath is covered with several layers of impregnated paper and a layer of tarred jute to form a suitable bedding for the armouring. This jute layer has a minimum thickness of at least 1.5 mm. (0.059 inch).

Over the jute bedding is a layer of galvanised iron wires of thickness not less than 1.4 mm. (0.055 inch).

A final layer of tarred jute is provided of thickness at least 1.5 mm. (0.059 inch).

Dimensions of Land Cable.—

Weight: (about) 5250 kg. per km. (9.57 tons per naut).

Overall diameter: (about) 40 mm. (1.575 inches).

The laying of the submarine cable took place on August 8th, 9th and 10th, 1930. The French shore end was landed from a barge and a coil of surplus cable about 0.119 nauts long was buried outside the cable hut. The landing operations took rather a long time, and kinking took place, which resulted in a full contact developing between the pairs in the centre quad at a distance of 0.865 nauts from the cable hut. The necessary repair was carried out by the cable ship "Norderney" and the War Department's steam vessel "Katharine" on August 17th. Some stages in the landing of the English shore end by the "Katharine" are shown in Figs. **1**, **2**, and **3**. The end in this case was cut to length.

The land cable was laid and balanced to the same electrical specification as the submarine cable, but the method of balancing differed from English procedure in that the quads and wires were jointed straight (colour to colour), balance being obtained by the insertion of condensers at certain joints. The completed land cable was

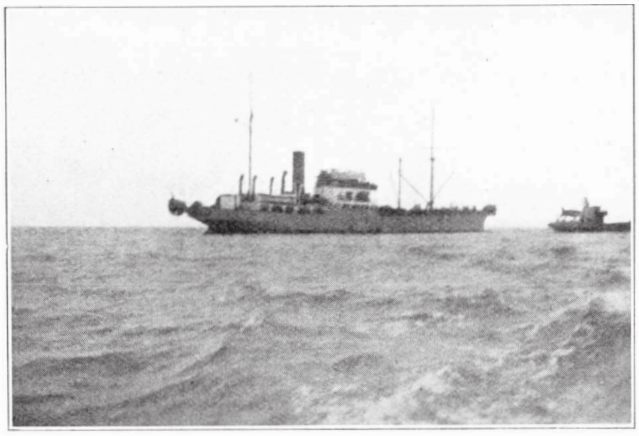


FIG. 1.—" KATHARINE " LEAVING " NORDERNEY."

tested by the French Administration, and it is understood that it complied in every way with specification requirements.

Tests made on the submarine cable from the Seabrook end gave results almost identical with those on the completed system, which are described below. The land and submarine cables were jointed together in the cable hut at Le Portel, crosses being introduced for the reduction of cross-talk.

The completed system of length 34.36 nauts from Seabrook to Boulogne Repeater Station was tested from the Seabrook end by officers from the Research Section of the Engineer-in-Chief's Office, G.P.O., and from the Boulogne end by the French Administration, in co-operation with the contractors. The electrical characteristics obtained from these tests will now be summarised and discussed.

FIG. 2.—PULLING END ASHORE FROM " KATHARINE."

DIRECT CURRENT TESTS.

Conductor Resistance: average of 28 cores = 12.36 ohms per naut. The Resistance Unbalance was small, the maximum, expressed as a percentage of the loop resistance, being 0.035.

The Insulation Resistance was measured with 300 volts, between each core and the remainder earthed, after one minute electrification. The average value was 47,500 megohms per naut for the completed and terminated cable. On the submarine portion alone before terminating, an average value of 76,900 megohms per naut was obtained, which is a normal value for air space submarine cables with loose paper wrapping.*

D.C. Capacity: Average of 14 side circuits = 0.078 μF per naut.

Average of 7 phantom circuits = 0.218 μF per naut.

FIG. 3.—LANDING THE END.

ALTERNATING CURRENT TESTS.

1. *Cross-talk.*—Table No. 1 gives the results of tests made with normal Post Office apparatus from Seabrook, the source of disturbance being speech or reed hummer as stated. Quads were terminated with a suitable resistance network at the distant end. The actual readings were in millionths of the disturbing current, but these have been converted to the power transference ratio between disturbing and disturbed circuits expressed in decibels, after correcting for impedance differences in line and apparatus.

* *c.f.* " *The Anglo-Dutch No. 3 Telephone Cable,*" *by A. B. Morice, B.Sc. (Eng.), A.M.I.E.E. P.O.E.E.J., Vol. 19, Part 3.*

Distant end readings are also corrected for the attenuation of the disturbing circuit.

Table No. 2 gives the results of tests made with Siemens and Halske apparatus at Boulogne. In this case the cross-talk attenuation was measured at frequencies of 650, 800, 1100 and 1900 cycles per second, say b_1, b_2, b_3, and b_4, and the corresponding mean value, b, of the cross-talk attenuation is :—

$$b = -\log_e \tfrac{1}{4} (e^{-b_1} + e^{-b_2} + e^{-b_3} + e^{-b_4})$$

It is noted that the distant end values measured in this way are higher than the values measured with Reed Hummer and normal Post Office apparatus.

The cross-talk attenuation between any two circuits in different quads was never less than 76 decibels, and was generally very much higher.

The specified minima were :—

Side to side in the same quad	74 decibels.
Side to phantom in the same quad	61 decibels.
Between any circuits in different quads	74 decibels.

It will be seen that the specification was satisfactorily met.

The cross-talk-frequency characteristics of the circuits in quad V. are given in Fig. **4.**

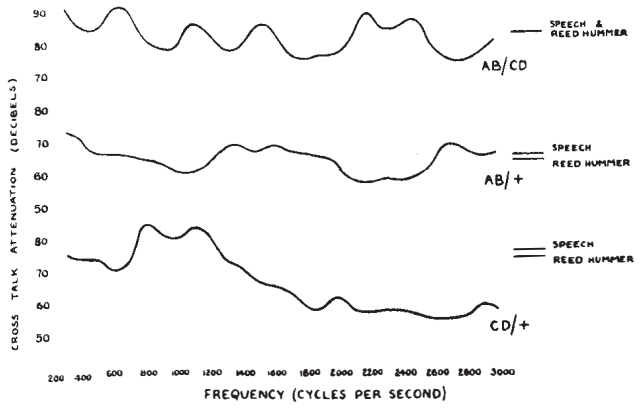


Fig. **4.**—Near end Cross-talk Frequency Characteristics of Pairs 9 and 10. Tested from Seabrook.

2. *Characteristic Impedance and Uniformity of Electrical Constants.*—The characteristic impedance of each pair and each phantom circuit was measured at Seabrook over a range of frequencies from 300 to 3000 cycles per second. Curves for a side and a phantom circuit are given in Figs. **5** and **6**. The maximum deviation of the impedance from a mean smooth curve is

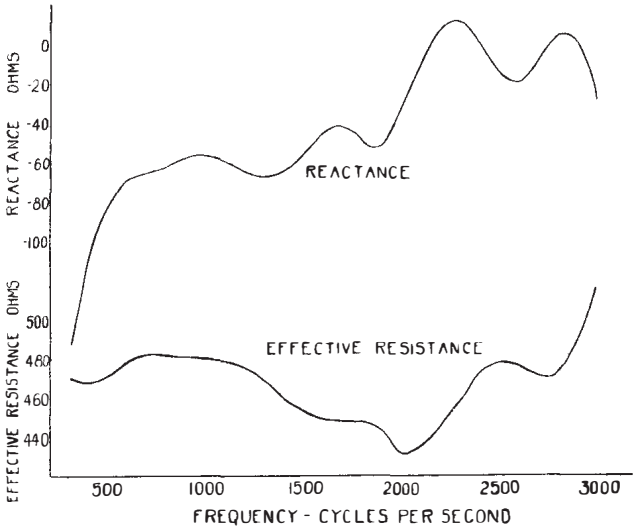


Fig. **5.**—Impedance Frequency Characteristics of Side Circuit over Audio range.

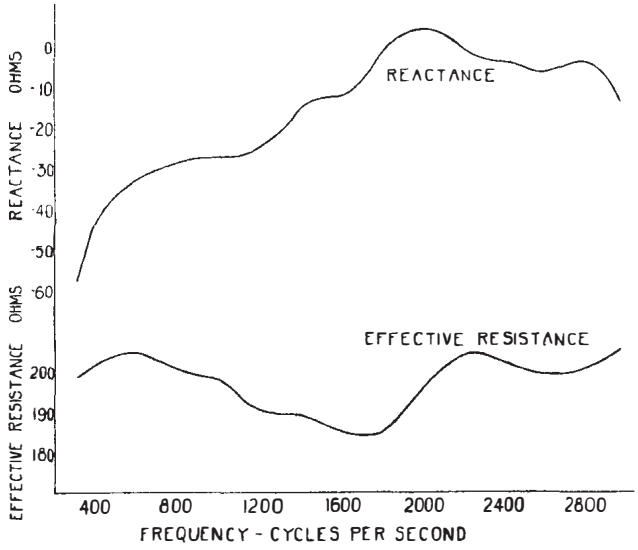


Fig. **6.**—Impedance Frequency Characteristic of Phantom Circuit.

on the whole higher than that obtained on similar cables in recent years, and exceeded 5% in the case of two side and three phantom circuits. It was also found that there is a considerable difference in shape between the curves of the different pairs. Impedance irregularities are caused by uneven distribution of the electrical

constants along the cable, and a careful scrutiny of all the curves indicates that there is a length of some 16 nauts commencing about 9.5 nauts from Seabrook which is of different impedance from the remainder of the cable, causing the deviations noticed.

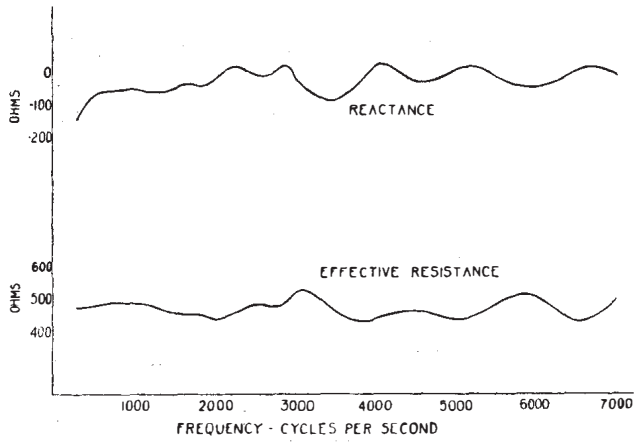


FIG. 7.—IMPEDANCE FREQUENCY CHARACTERISTICS OF SIDE CIRCUIT FROM 300 TO 7,000 CYCLES PER SECOND.

Table 3 gives the mean A.C. constants at three frequencies of all the pairs and all the phantoms in the outer layer of a short length of cable cut off the Seabrook end.

Fig. **7** shows the impedance-frequency characteristics over a range of frequencies from 300 to 7000 cycles per second for the side circuit of which the characteristics at audio frequencies are given in Fig. **5**. All side circuits were measured over the longer range, and it appears that from the point of view of impedance deviation some difficulty may be experienced in working broadcast repeaters.

3. *Transmission Efficiency.*—Fig. **8** shows the attenuation-frequency variation of side and phantom circuits over a range from 300 to 3000 cycles per second, together with the specified maximum values at certain frequencies, which are not exceeded. The difference of attenuation between $f = 300$ and $f = 3000$ is 0.0069 and 0.0072 nepers per naut loop for the side and the phantom circuits respectively. Fig. **9** shows

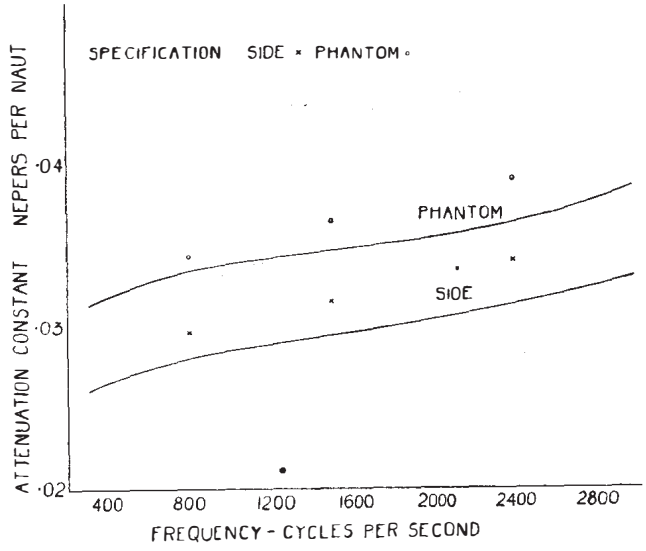


FIG. 8.—ATTENUATION FREQUENCY CHARACTERISTICS OVER AUDIO RANGE.

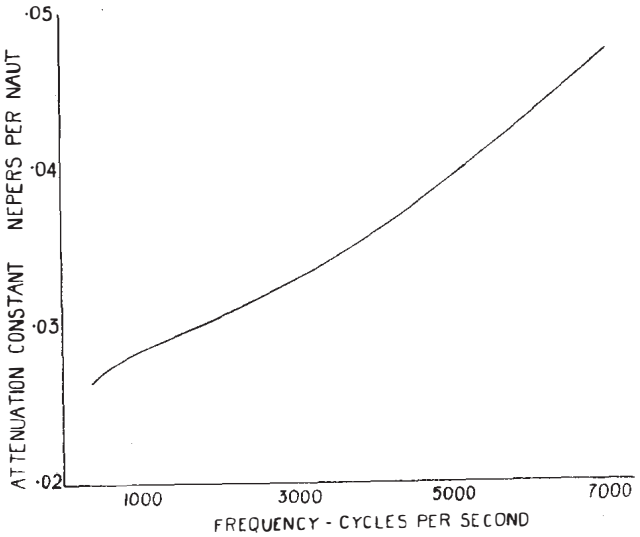


FIG. 9.—ATTENUATION FREQUENCY CHARACTERISTICS OF SIDE CIRCUIT FROM 400 TO 7,000 CYCLES PER SECOND.

the attenuation-frequency variation of a side circuit from 300 to 7000 cycles per second.

The velocity of propagation is about 27,000 and 23,000 nauts per second for side and phantom circuits respectively, and the wavelength constant is proportional to frequency.

4. *Determination of Constant for Fault Localisation by A.C. methods.*—When fault localisation is being carried out by the sending end impedance method* it is necessary to use an empirical constant K obtained by tests on the

* *"A.C. Methods of Fault Localisation in Telephone Cables," by W. T. Palmer and M. E. Tufnail. P.O.E.E.J., Vol. 23, Part 1.*

completed cable. The value obtained in this case was

$$K = 13{,}650$$

This should be only slightly different from the value $\frac{1}{2\sqrt{CL}}$, but owing to irregular distribution of the electrical constants the mean value of the inductance and capacity after laying are not known. Taking the mean value of the inductance tested on factory lengths as 17 mH. per naut, and using the mean D.C. value of the capacity, *i.e.*, 0.078 μF per naut, we have

$$\frac{1}{2\sqrt{CL}} = 13{,}720$$

which is 0.51% greater than the measured value.

Some further considerations of fault localisation in this particular case are given in an appendix to this article.

The author's thanks are due to Mr. E. H. Jolley, of the Research Section, Engineer-in-Chief's Office, for supplying the photographs included in this article.

TABLE 1.

NEAR END AND DISTANT END CROSSTALK, WITHIN QUADS.

Tested at Seabrook with normal P.O. apparatus.

All values in decibels, after correction for impedance differences.

Quad.	AB/Phantom.			CD/Phantom.			AB/CD.		
	N.E.		D.E.	N.E.		D.E.	N.E.		D.E.
	Speech.	Reed Hummer.	Reed Hummer.	Speech.	Reed Hummer.	Reed Hummer.	Speech.	Reed Hummer.	Reed Hummer.
I.	69	67	66	76	71	69	90	90	81
II.	73	70	67	73	67	67	90	87	79
III.	72	70	69	68	70	66	80	80	90
IV.	69	64	73	67	64	66	85	87	78
V.	64	63	65	75	72	65	82	82	87
VI.	73	72	66	73	72	72	80	80	87
VII.	72	66	67	72	67	66	93	90	78

TABLE 2.

NEAR END AND DISTANT END CROSSTALK, WITHIN QUADS.

Tested at Boulogne with Siemens and Halske apparatus.

Mean of readings at frequencies of 650, 800, 1100 and 1900 cycles per second. All values in decibels.

Quad.	AB/Phantom.		CD/Phantom.		AB/CD.	
	N.E.	D.E.	N.E.	D.E.	N.E.	D.E.
I.	72	73	69	78	90	90
II.	73	73	69	77	90	88
III.	73	74	69	71	92	95
IV.	70	78	69	70	89	80
V.	72	69	70	76	87	100
VI.	70	70	74	78	82	94
VII.	75	75	70	75	85	88

TABLE 3.

A.C. CONSTANTS, PER NAUT. LOOP.

Mean values of circuits in outer layer, measured on 0.15 naut. length.

Circuits Tested.	Cycles per second.	Characteristic Impedance. Vector Ohms.	Attenuation Constant.	Propagation Constant.	Resistance Ohms.	Inductance Millihenries.	Capacity Microfarads.	Leakance Micromhos.
Sides	800	$477\angle 7°42'$	0.0264	$0.192/82°6'$	24.66	18.28	0.0773	1.47
	1500	$471\angle 4°15'$	0.0283	$0.355/85°26'$	25.62	17.72	0.0790	4.25
	2400	$472\angle 2°44'$	0.0304	$0.564/86°55'$	27.03	17.67	0.0791	7.41
Phantoms	800	$200\angle 7°32'$	0.0303	$0.225/82°15'$	11.85	8.64	0.2231	4.35
	1500	$198\angle 4°3'$	0.0311	$0.415/85°42'$	11.88	8.60	0.2226	9.37
	2400	$197\angle 2°31'$	0.0334	$0.662/87°7'$	12.30	8.62	0.2222	22.48

APPENDIX.

Fault localisation on the Anglo-French (1930) Cable from Canterbury Repeater Station.

Seabrook Cable Hut is unattended, and in it are situated transformers for changing from four-wire working in the Canterbury-Seabrook coil-loaded underground cable to two-wire working in the Seabrook-Boulogne continuously loaded submarine cable. Precision testing apparatus is permanently located at Canterbury Repeater Station and in order to take full advantage of this, special arrangements are necessary in the case of this cable.

1. *Direct Current Methods.*—In order that daily observation may be kept of the insulation resistance of circuits from Canterbury to Boulogne, spare unloaded wires in the Canterbury-Seabrook cable have been joined at Seabrook to the centre points of the submarine cable side of the phantom circuit transformers. This allows of an insulation measurement on a circuit composed of one wire of the Canterbury-Seabrook cable, the line windings of phantom and side circuit transformers at Seabrook, four wires in parallel in the submarine cable, and the line windings of side and phantom transformers at Boulogne. Should a cable breakdown occur, this circuit may be used for a Varley test or other direct current localisation from Canterbury by looping the centre point of the line side of a phantom transformer at Boulogne to a good wire in the Anglo-French (1926) Cable. The resultant localisation in ohms can be interpreted in terms of distance by making due allowance for the composite nature of the circuit.

2. *Alternating Current Method.*—Suppose a loaded pair in the Canterbury-Seabrook cable is put straight through at Seabrook to a pair in the submarine cable on which a fault occurs at a distance l' nauts from Seabrook.

Electrical energy supplied at Canterbury will be partly reflected at Seabrook, and a part will travel on to the fault, where further reflection will take place. The reflected energy from the fault will partly be reflected at Seabrook, and a part will return to the sending end.

Considering any one frequency f_1, the phase of a reflected wave from Seabrook on its return to the sending end will be $2\alpha_1 l + \phi_1$,

where l is the distance in nauts from Canterbury to Seabrook

α_1 is the wave-length constant of the Canterbury-Seabrook cable at frequency f_1

ϕ_1 is the change in phase produced at the discontinuity at Seabrook.

The phase of a reflected wave from the fault on its return to the sending end will be $2\alpha_1 l + \psi_1 + 2\alpha_1' l' + \psi_1' + \phi_1'$

where α_1' is the wave-length constant of the Seabrook-Boulogne cable at frequency f_1

ϕ_1' is the change in phase produced by the fault

ψ_1 is the change in phase in passing from the land to the submarine cable

ψ_1' is the change in phase in passing from the submarine to the land cable.

At a second frequency f_2 the corresponding phases are $(2a_2l+\phi_2)$ and $(2a_2l+\psi_2+2a_2'l'+\psi_2'+\phi_2')$

where a_2, a_2', ϕ_2, etc., have the same significance as a_1, a_1', ϕ_1, etc., but at frequency f_2 instead of f_1.

Suppose an impedance-frequency run, using the parallel resonance bridge, is taken on a faulty circuit, and that from each resistance reading is subtracted the reading obtained on the same circuit when there is no fault, then obviously the phase change due to first reflection is practically the same at any given frequency in each case, and differences between the two curves are mainly due to first reflections at the fault, secondary reflections having little effect. Then if f_1 and f_2 are the frequencies of two successive maximum points on the difference curve, we have

$$(2a_2l+\psi_2+2a_2'l'+\psi_2'+\phi_2')-(2a_1l+\psi_1+2a_1'l'+\psi_1'+\phi_1')=2\pi \quad \ldots\ldots(1)$$

Whence $l' = \dfrac{2\pi+2l(a_1-a_2)+(\psi_1-\psi_2)+(\psi_1'-\psi_2')+(\phi_1'-\phi_2')}{2(a_2'-a_1')}$ .....(2)

Now in this case we may assume that $\psi_1=\psi_2$, $\psi_1'=\psi_2'$, and $\phi_1'=\phi_2'$.

Then $l' = \dfrac{\pi+l(a_1-a_2)}{(a_2'-a_1')}$ .....(3)

But for loaded cables $a \fallingdotseq 2\pi f\sqrt{CL}$

Then $l' \fallingdotseq \dfrac{1}{2(f_2-f_1)\sqrt{C'L'}} - \dfrac{l\sqrt{CL}}{\sqrt{C'L'}}$ .....(4)

Comparing this with the normal alternating current location formula, *i.e.*, $l = \dfrac{K}{f_2-f_1}$, we have

$$l' \fallingdotseq \frac{K'}{f_2-f_1} - \frac{K'}{K}\,l \quad \ldots\ldots(5)$$

where K′ is the fault localisation constant for the submarine cable,

and K is the fault localisation constant for the underground cable.

It is seen that the term $\dfrac{K'}{K}\,l$ in equation (5) is the length of submarine cable that would give the same phase change as l miles of underground cable. This term may be obtained directly from a knowledge of K′, K, and l, or may be determined by introducing at a known distance l' along the submarine cable a contact resistance across the selected pair.

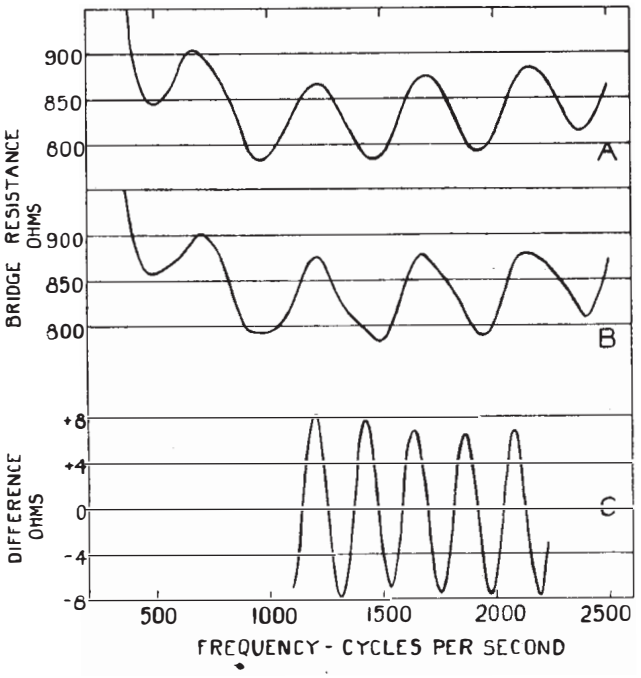


FIG. 10.—A. NORMAL IMPEDANCE (BRIDGE RES. READINGS).
B. IMPEDANCE WITH 500 OHM FAULT AT BOULOGNE.
C. DIFFERENCE CURVE B—A.

Fig. **10** shows some results of tests made in this way.* Curve A shows the bridge resistance readings obtained when testing on pair 5 of the underground cable joined straight through at Seabrook to pair 5 of the submarine cable, which was looped at Boulogne to an electrically long similar circuit. Curve B shows the bridge resistance readings obtained on the same circuit when a contact fault of 500 ohms was put across

* *Cf. Fig.* **8**, *p. 48, P.O.E.E.J., Vol. 23, Part 1. "A.C. Methods of Fault Localisation in Telephone Cables," by W. T. Palmer and M. E. Tufnail.*

pair 5 at Boulogne. Curve C shows the difference curve, over a portion of the range. Careful exploration at close frequency intervals of certain maxima gave $(f_2 - f_1)$ as 219 cycles per second. The length l' of the submarine cable is 34.36 nauts, and the localisation constant K′ is 13,650. Substituting these values in equation (5)

$$\frac{K'}{K} l = \frac{13{,}650}{219} - 34.36 = 62.32 - 34.36 = 27.96 \text{ nauts} \quad \ldots\ldots(6)$$

Since l is known, *i.e.*, 17.257 nauts., we can obtain a value of K from equation (6).

$$K = \frac{K'l}{27.96} = \frac{13{,}650 \times 17.257}{27.96} = 8{,}425 \quad \ldots\ldots(7)$$

The capacity per naut. of the underground cable is about 0.076 μF per naut, and the inductance per naut about 44.7 mH. Using these values we obtain

$$K = \frac{1}{2\sqrt{CL}} = 8{,}580 \quad \ldots\ldots(8)$$

This agrees fairly well with the value obtained practically from equation (7).

If a pair in the underground cable is joined through at Seabrook to a pair in the submarine cable and this is terminated at Boulogne with its characteristic impedance in ohms—say, 480 ohms—then an impedance-frequency run can be taken to be kept as a reference. A portion of this run—say, from 1600 to 2200 cycles per second—should be measured at close frequency intervals. Then, on a fault occurring, which is located in the submarine cable by direct current tests, the same pairs must be put through at Seabrook and terminated at Boulogne with the same resistance. An impedance-frequency run can now be taken on the faulty circuit, the same close intervals being used between 1600 and 2200 cycles per second. By plotting the differences between this series of results and those previously taken for reference, a value can be obtained for the frequency interval $(f_2 - f_1)$ between successive maxima, and then the distance from Seabrook to the fault, l' nauts, is given by

$$l' = \frac{13{,}650}{f_2 - f_1} - 27.96 \quad \ldots\ldots(9)$$

In view of rather irregular distribution of the electrical constants in the submarine cable, the constant K′ = 13,650 may not be quite accurate for faults in all positions along this cable. It is also possible that seasonal temperature variations will be found to have a slight effect on the experimental value of the term $\frac{K'}{K} l$ in equation (5). It is possible, therefore, that localisations by this method may not be within the 1% accuracy obtained in cases where the same type of cable is employed throughout between test points, but the method should prove useful in any case where the direct current methods present difficulty.

VENTILATION OF BUILDINGS: INCLUDING THE NEW SYSTEM STANDARDISED FOR USE IN AUTOMATIC TELEPHONE EXCHANGES.

J. E. McGregor, A.C.G.I., A.M.I.E.E.

IN view of the recent issue of the new Technical Instruction No. XXXIX. on the Ventilation of Buildings, and the interest evinced at meetings of the I.P.O.E.E. it seems opportune to make a few comments both on the need for mechanical ventilation and on the systems adopted by the Department.

The ventilation of buildings is a subject of increasing importance, especially in large towns, where buildings are growing in size and the provision of natural ventilation is becoming very difficult. It is complicated by the fact that the free air surrounding the buildings is no longer pure, but is partly vitiated by exhaust gases from motor cars and impregnated to a greater or less extent, depending on the neighbourhood, by dust and smoke.

Windows which give adequate ventilation for smaller rooms are less effective or cause draughts in larger rooms. They often remain closed due to inclement weather or the whims of the staff employed, and even when conditions are otherwise favourable may be kept closed to exclude dust or noise. For these reasons artificial means of ventilation, which will be effective at all seasons of the year and are independent of the idiosyncrasies of the staff employed in the building, are becoming increasingly necessary.

Artificial ventilation may be carried out by means of *Suction* systems in which the air is drawn out of the buildings by fans, the ingress of air being more or less uncontrolled, or by *Plenum* or pressure systems in which the air is entirely under control, it being drawn in from the more suitable position as regards the purity of the air, filtered to remove the greater part of its dust and smoke content, and delivered as, and where, required in the building under a slight pressure. When desired, owing to manufacturing processes such as in cotton mills or for other reasons, it may be entirely reconditioned as regards its temperature and humidity.

In any scheme of ventilation it is necessary to take into account the dimensions of the room and the number of staff employed, the nature of the work carried out and whether the circulation of the air is likely to be impeded. As will be seen later, this is one of the most serious factors in the case of automatic apparatus rooms, the other being impurities in the air. Consideration has also to be given to the reconditioning of the air and the removal of dust and soot if necessary.

Until recently the percentage of carbon-dioxide, the waste product of fuel consumption and of the natural process of breathing, has been considered of vital importance, but it is now known that this percentage may be very high without injuriously affecting the human body as long as the air is in movement, other beneficial factors being moderate temperature and humidity. This is because the feeling of well-being is dependent on the temperature of the body being kept constant by the evaporation of moisture from the skin which depends on these conditions, and on the removal of the moisture and CO_2 emitted from the lungs in breathing.

The percentage of CO, the product of incomplete combustion of fuel which is poisonous, does not generally have to be considered except in the case of the ventilation of garages, but with the increasing number of motor cars in confined streets it becomes advisable to arrange for the ingress of air to be as much removed from the street level as possible. From the point of view of the prevention of the transmission of disease or illness an ample supply of fresh air and its free circulation are matters of prime importance.

Owing to the necessity for maintaining movement of the air, the ventilation of Apparatus Rooms in Automatic Exchanges becomes a very urgent matter, as, although the number of staff employed is not large in proportion to the gross volume of the rooms, the volume of free air in the room is greatly reduced and the flow of air very greatly impeded by the rows of apparatus racks, closely spaced and extending practically to the ceiling. This arrangement of racks causes a feeling of confinement and stuffiness which can only be dispelled by the introduction

of a considerable volume of fresh air moving with as high a velocity as is permissible.

Complete reconditioning of the air owing to our temperate climate, need not generally be considered except as mentioned above in connection with certain manufacturing industries. The plant required is expensive and bulky, as, when employed, the incoming air has to be washed, the free moisture removed, the moisture content reduced by freezing, further moisture added if required and the temperature readjusted.

It is necessary, however, in many cases and especially in Auto Apparatus Rooms, to remove as much dust and smoke from the air as possible and this, though easy as regards material dust, is not easy as regards smoke. Air filters are of many types; they may consist of water sprays, screens of some textile material, or screens containing material such as metal turnings, expanded metal, or small pieces of tube jumbled together, the material being coated with a viscous oil on which the dust from the air is deposited as the air passes along the tortuous paths thus provided by the filter.

The Department has now had experience of a large number of the various air filters on the market and has found that a perfect filter does not exist. Practically any type of filter is effective as regards material dust, but it is a very different matter as regards smoke and the very fine soot carried by the smoke; washing the air is no better in this respect than using textile and viscous filters. Textile filters can be obtained which are comparatively very effective, but in a short time they become permanently more or less choked, involving a reduction in the amount of air passed and an excessive cost in maintenance. For small installations, however, a filter has been evolved to meet our requirements and this is embodied in what is known as the Plenum Unit which is referred to later. In this case the filtering material is of cellulose and is so cheap that it becomes economical to throw away the used, and replace it by new, material. Although this is practicable for small installations the cost of replacement becomes serious where large installations are in question and a viscous type of filter is then used, the efficiency of which is high, especially when used in the duplex form which has been standardised for use in dirty neighbourhoods.

Many types of viscous filter have been used by the Department which have been found either less efficient than the type standardised or to present greater difficulties in cleaning, in some cases permanent choking occurring as in textile filters of the more efficient types. To clean filters of the viscous type it is necessary to use a hot soda solution which does not, however, soak out all the interior dirt in a sealed type of filter cell, and the standard type has the great advantage that it is a simple matter to empty out the filtering material, clean them separately and then reassemble the filter.

Although by the use of air filters practically all the material dust and a considerable percentage of the smoke and soot can be removed, it should be borne in mind that the work of the filter can be largely negatived if dust is permitted to enter the room by other means. Dust can enter the room on the clothing and shoes of the staff, through open doors, especially if stairs and corridors are not kept quite clean, through fresh air inlets behind radiators, if they have not been shut as they should be when Plenum systems have been installed, and through the flap ventilators, which are installed to provide for the egress of the air, if they are not maintained in good condition.

Reverting to the *Suction* system of ventilation, this is usually installed where there is no need to provide air freed from dust, where there is no possibility of drawing the air supply from tainted sources, and where it is necessary to remove fumes as in kitchens and dining-rooms or dust as in bag-rooms. Usually one or more simple extractor fans are fitted in the windows on one side of the building, fresh air being admitted through the windows on the opposite wall. Where possible, if more than one fan is installed, they should be placed on different frontages, as a fan of this type may be rendered entirely ineffective by a wind. In some cases it is preferable to instal ductwork so as to draw the air out at a large number of points, in which case a cased centrifugal fan usually becomes necessary, as the open type of propellor fan cannot draw the air effectively against the resistance to air flow caused by the ductwork. For the same reason, this type of fan is next to useless if it is required to filter the air at all satisfactorily. It is also necessary that air should be admitted

freely to the room through open windows or special apertures. When there are complaints as to the working of a suction ventilating system, it will frequently be found that all windows are closed so that air cannot enter freely, or that windows are open adjacent to the fan, thus short-circuiting the circulation of air across the room. Generally, when it is necessary to filter the air the Plenum system is much the most satisfactory, as there is greater freedom in choosing the point at which the fresh air can be drawn and the whole system is under control.

In the case of the earlier automatic telephone exchanges it was necessary to consider the humidity as well as the provision of air, as the material used was to a certain extent hygroscopic. This difficulty was overcome by a choice of materials, but the question of efficient ventilation remained.

In this case we were faced with the following problems: first, the provision of sufficient fresh air freed as far as possible from dust, as this is deleterious to the maintenance of the apparatus, and secondly, the proper circulation of the air so that stagnant pockets of air, possibly holding germs of disease, should not be left between the racks. Natural ventilation by the opening of the windows is out of the question, not only on account of dust troubles, but owing to the impossibility of providing efficient circulation of the air by this means. The provision of sufficient air by mechanical means presents no difficulty, except that owing to other requirements it is not always possible to obtain the best situation for the fan room, and, even when such a position has been chosen from the plans of the building, it may be found when the building itself and other buildings around it have been erected so that smoke from their chimneys is driven directly on to the air inlet by the prevailing wind.

As regards dust, what may elsewhere be a quite satisfactory filter is not necessarily satisfactory in this case, owing to the enormous settling surface presented by the apparatus. In an ordinary room the circulation of air is practically unimpeded and the very fine particles which will pass the filter will remain in the air and be carried out by it, but here we have the racks extending practically to the ceiling, the circulation of air seriously impeded, a large surface which will collect this dust and in addition the attraction of electrified surfaces for dust.

The type of viscous filter employed in the new standard system has been selected after careful consideration of the various types and makes available, as it is found the most suitable as regards efficiency, maintenance and space required. The difficulty of circulating the air has been overcome by the use of the new rotating outlets which drive the air downwards and outwards. The consequent turbulence of the air should prove beneficial both in preventing air pockets remaining between the racks and in minimising the tendency of the fine dust or soot passed by the filter to settle out of the air on to the racks.

The amount of fresh air supplied is considerably greater than that actually needed for breathing purposes by the staff, owing to the necessity of scouring out the vitiated air between the racks and also removing a certain amount of low grade heat given out by the apparatus.

In the smaller exchanges it is not feasible to provide special fan rooms and expensive plant owing to cost considerations; a system has been designed accordingly in which the fan and filter form a self-contained " Plenum Unit " and the ductwork is simple and can be erected by the Department's staff. The filter used in these units is very efficient and the dirty filtering material is simply thrown away instead of being cleaned, thus simplifying the maintenance to a minimum.

It will generally be found that the air supplied is by no means excessive in warm weather. In colder weather, however, when owing to changed conditions so much fresh air is not necessitated, the staff may find it convenient to run the fan at full output for about an hour to thoroughly clear out the air of the apparatus room and then to reduce the amount of air circulated by using the damper provided in the main duct. This method of working will incidentally reduce the slight amount of dust brought into the exchange by the air.

BACK-TO-BACK TESTING OF EXCHANGE MOTOR GENERATORS.

R. MacWhirter, B.Sc., Scotland West.

A CONSIDERATION of the familiar Hopkinson Test for D.C. Motors suggests the possibility of applying a similar test to motor-generators. The essence of the Hopkinson or other back-to-back test lies in the use of two identical machines connected to the supply mains and coupled together mechanically or electrically in such a way that one machine drives (*via* the mechanical or electrical coupling) the other machine, which generates current back to the line. Fig. 1 indicates the circulation of energy in the case of motor-generating sets.

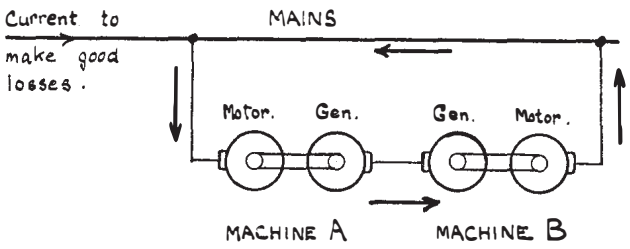


FIG. 1.

The advantages of the method are:—

(1) *Economy.*—Only the difference between the power taken by Machine A, and the power generated by B, is drawn from the supply.

(2) *Ease of control.*—The extent of loading is easily controlled by simple adjustment of field excitation. Load current is much more stable than when a liquid resistance is used.

(3) *Saving of time.*—While temperature measurements are being made on, say, Machine A, Machine B is simultaneously warming up. Thereafter only a short run is necessary with Set A inverted (*i.e.*, generating at the motor end) instead of Set B, to stabilize the temperature and complete the test on the latter set. In Telephone Exchanges the circumstances are peculiarly suitable for such a test, as two machines are usually available, together with a well equipped power-board.

Case 1—D.C. Supply.—No difficulties present themselves.

Assume two motor-generators with a reasonable range of field control, connected up as shown in Fig. 2. As a rule, a simple cross-

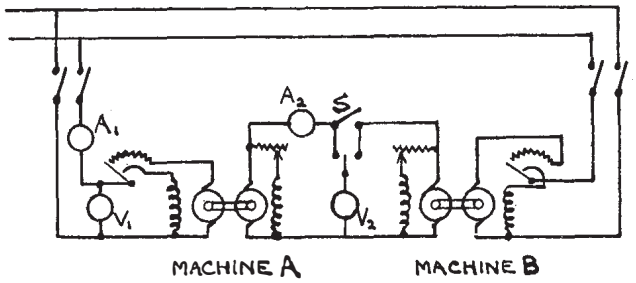


FIG. 2.

connection at the back of the board will enable the above circuit to be constructed. Fig. 3 shows a particular Ericsson board on which only a link L has to be inserted as shown. Switch S is used as a paralleling switch, and it will be seen that the ammeter and voltmeter on the board can be used as the output instruments, and the circuit-breaker retained in circuit for protection.

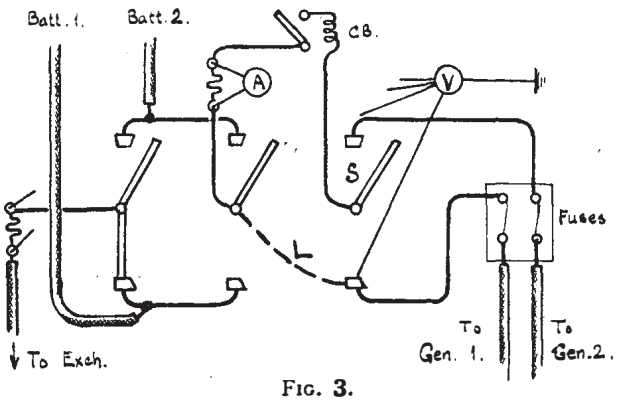


FIG. 3.

It will be seen (Fig. **2**) that we have a voltmeter and ammeter connected in both the Input and Output circuits of Machine A, the machine which runs normally.

The test procedure is as follows:—

Both machines are started up with switch S opened. Field resistances are adjusted to give normal voltage (say, 46 volts) at the terminals, and switch S is closed, thus paralleling the two machines. A reading of V_1 and A_1 will now give the no-load power taken by one machine.

The excitation of Machine A is now increased. Voltages no longer balance and a current circulates round the closed circuit formed by the armatures of the two generators. This is indicated on A_2, while V_2 registers the increased voltages. Next, B's excitation is reduced until V_2 returns to its normal value. Notice that by reducing the excitation of B we have *increased* the difference between the E.M.Fs. of the machines: this manifests itself in a further rise in the reading of A_2 as we bring V_2 back to normal.

V_1 and A_1 now indicates the input corresponding to a load of A_2 amperes.

The process is repeated for a further increase in loading, and continued until Machine A is fully loaded. The usual tables of volts, amperes, watts and efficiency are then constructed. The instruments may then be re-arranged and Machine B run normally with A inverted.

Case 2—Alternating Current Supply.—It should be realised that an induction motor will function equally well as an induction generator, provided it is connected to an A.C. supply.

In normal operation, the magnetic lines of force in an induction motor travel round the shell at synchronous speed, *i.e.*, in step with the alternations of the supply voltage. The rotor rotates by virtue of the reaction between the current it carries and the rotating magnetic flux. Now the rotor currents can only be induced by rotor conductors cutting the magnetic lines of force. In other words the rotor speed must differ from the speed of rotation of the flux. Actually, the rotor revolves somewhat more slowly than the flux, the difference of speed adjusting itself to a value such that the induced rotor currents are just sufficient to overcome the torque imposed by the load.

Now suppose the rotor is driven *above* synchronous speed by artificial means; the rotor currents, and by transformer action the stator currents, will have a direction opposite to the currents considered above. In other words, the machine is running as a generator.

For those familiar with the Circle Diagram of the induction motor, the state of affairs is best represented vectorially as in Fig. **4**, where—

OV: represents applied voltage.
OI_0: represents no-load current.
Oø : represents the flux.

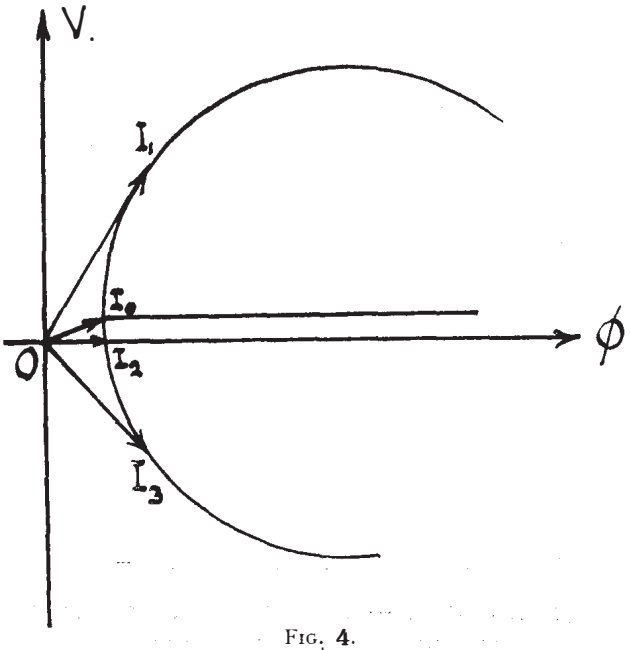


FIG. **4**.

As the load is taken off and the rotor speed increases, OI_1, the load current, gradually retreats towards OI_0. If the rotor is further speeded up OI_1 will move to position OI_2 when the machine losses are just overcome, and finally to some position such as OI_3, when the machine will be generating back into the mains.

To run a back-to-back load test, then, on A.C. driven plant, the process is exactly the same as with D.C. The generators are paralleled as before, the excitation of the generating set being increased while that of the inverted set is reduced, until the machines are fully loaded.

It may sometimes be necessary to insert an extra resistance in the field circuit of the inverted set, in order to reach the higher values of load current. It is unnecessary to attempt to keep

the output voltage rigidly at the specified figure, as efficiency does not vary seriously with output voltage.

A.C. Input and Power Factor.—Of the various methods of determining Input and Power Factor the " 2 watt-meter " method is the most generally convenient and accurate.

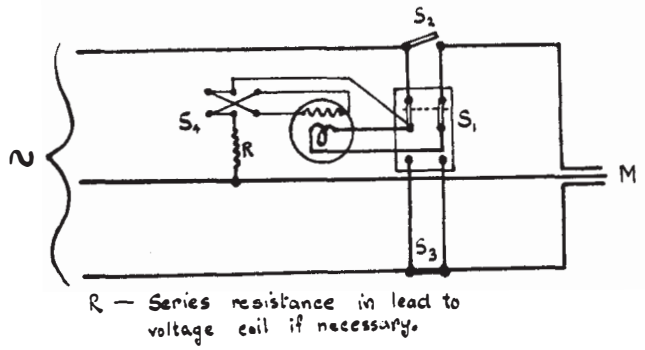


FIG. 5.

Fig. **5** shows a 3-phase motor with the two watt-meters connected in circuit: V are voltage coils, C current coils. In practice only one meter is used with a double-pole change-over, a reversing, and two single-pole switches. Special switches are available which enable the two latter to be dispensed with. The connections are as in Fig. **6**.

For each value of the load current, two watt-meter readings are taken, one for each position of the main double-throw switch S. The associated single pole switches S_2 and S_3 must, of course, remain closed, except when the blades of the double-throw switch are thrown to either pair of contacts, when the appropriate single pole switch is opened to obtain the reading.

In general, the two readings obtained for each loading are not equal. In fact where the power factor is low, one of the readings will be negative, and it is to obtain this negative reading that the reversing switch S_4 has to be used.

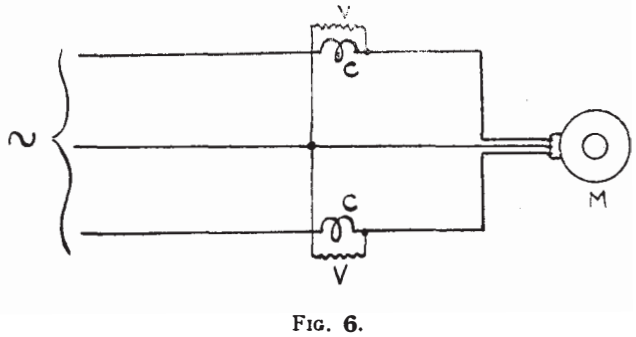


FIG. 6.

Assume we have obtained a pair of readings for some particular loading. Multiplied by the appropriate meter constant, we obtain two wattages W_1 and W_2. Then total input to the machine

$$W = W_1 + W_2$$

and calling the phase-angle between current and voltage θ, we have

$$\tan \theta = \sqrt{3}\,\frac{W_1 - W_2}{W_1 + W_2}$$

whence by using a set of trigonometrical tables, the power factor = cos θ is obtained.

To illustrate a complete test, the following table with sample calculations has been drawn up:—

1	2	3	4	5	6	7	8	9	10	11	12	13	14
D.C.		A.C. Watts				Speed RPM	Out-put	In-put	Effy %	$W_1 - W_2$	$\frac{\sqrt{3} \times W_1 - W_2}{W_1 + W_2}$	P.F.	Remarks
Amps.	Volts	(1)	W_1	(2)	W_2								
0	46	.26	1040	− 02	−80	1000	0	960	0	1120	2.02	.44	No-load
120	46	1.13	4520	.795	3180	972	5520	7700	71.7	1340	.302	.96	Full-load

Columns 1, 2, 3, 5 and 7 are observations.

Figures in columns 4 and 6 are obtained from those in 3 and 5 by multiplying by the watt-meter constant—in this case 4000.

Column 8 input is the product of columns 1 and 2.

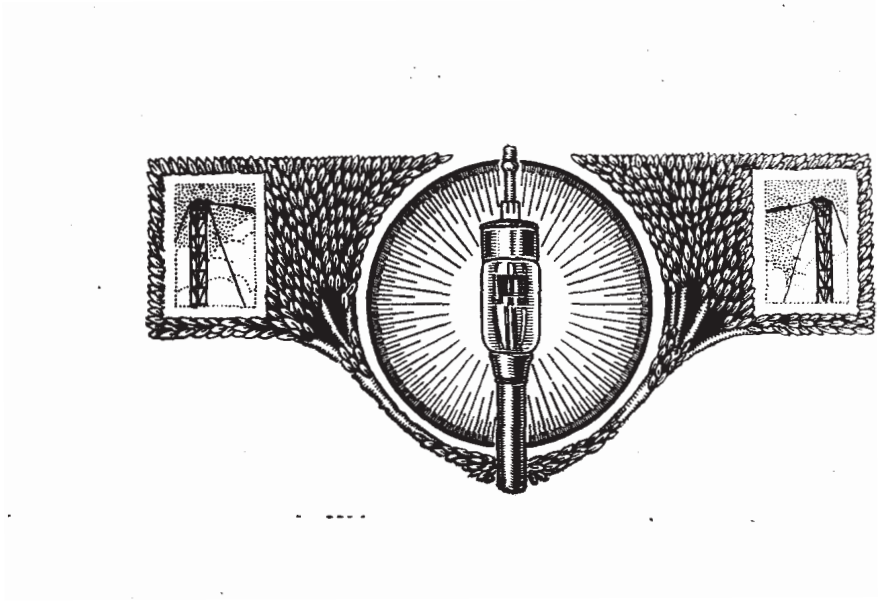
Column 9, output, is the sum of columns 4 and 6. (Note the effect of the minus sign in the no-load case). Then Efficiency (Column 10) is (Output)/(Input).

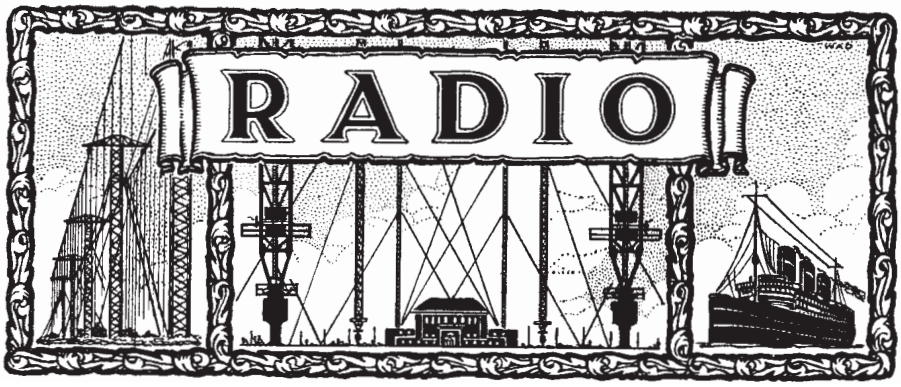
In column 11, values of $W_1 - W_2$ are listed and from this column and column 8 ($= W_1 + W_2$) we obtain column 12. These values we know to be $= \tan \theta$ so that by consulting a book of tables column 13 is readily obtained. *E.g.*, in the Full-load case, $\sqrt{3}\,\frac{W_1 - W_2}{W_1 + W_2} = .302$. Consulting our tables we find that 16°48′ is the angle whose tangent is .302; and turning to cosine tables we find that cos 16°48′ = .96, which value we enter as the Power Factor.

In the Hopkinson Motor-Test, where mechanical instead of electrical coupling between the machines is employed, the input W_1 to the first machine and the losses are measured, from which is calculated the output W_0 from the second machine; efficiency is then $\sqrt{\frac{W_0}{W_1}}$.

It might be asked whether such a test is feasible in the case of motor generators, for, if so, both measurements would be made on A.C. and with suitable switches a single watt-meter would enable all necessary measurements to be made. Such a test would, however, be less accurate than the Hopkinson. In the latter, both machines are almost equally loaded, so that an average load value against which to plot efficiency is capable of fairly accurate estimation. In the case of motor-generators, however, the losses of four machines in succession have to be made good, and the difference in loading between the first motor and last generator, (Fig. 1) is considerable. It is not, therefore, possible to assess an average load value with much accuracy.

A test was actually carried out on these lines, but results showed some 3% high when compared with those obtained by a direct efficiency test.





THE RADIO TELEPHONY TERMINAL.

W. H. SCARBOROUGH.

THE Radio Telephony Terminal is situated near the London Trunk Exchange, not only because London is a centre for the largest percentage of business interests for Overseas traffic, but also because the London Trunk Exchange offers ideal facilities for access to all long distance trunk routes throughout Great Britain and the rest of Europe with the minimum of transmission losses. At present the radio Telephony Terminal is the technical control point for seven commercial channels:—

(1) One long wave and three short wave circuits between Europe and the U.S.A., Canada, Cuba and Mexico.

(2) One short wave service to Australia, by which through connections can also be made from America to Australia.

(3) One short wave Marine Telephony service to the s.s. "Leviathan," "Majestic," "Olympic" and "Homeric" operating on the Atlantic routes.

(4) One short wave service to South America.

The method of operating the services is similar to ordinary 2-way telephone conversations, for neither the subscriber nor the trunk operator who controls the connections to the radio links have any indication that these circuits are different from ordinary line telephonic connections. Beyond the switchboard positions there is, however, an organisation of equipment and personnel vastly different from that usually associated with trunk and long distance telephone circuits.

Each radio telephony circuit is essentially a 4-wire circuit with an inter-connecting and control terminal at either end for extension to any 2-wire telephone system, with the exception that the marine telephony circuits terminate in a telephone booth on board ship.

From the radio terminal there is an independent one-way high quality transmission line for each transmitting and receiving station.

To indicate the transmission path from one subscriber to another reference is made to the long wave telephony circuit as below:—

Fig. 1.

New York to London.

New York Traffic operator.
New York terminal position.
70 miles of land line to Rocky Point Transmission Station.
3,240 miles of radio to Cupar (Fifeshire).
450 miles of land line, Cupar-London.
London terminal position.
London operator.

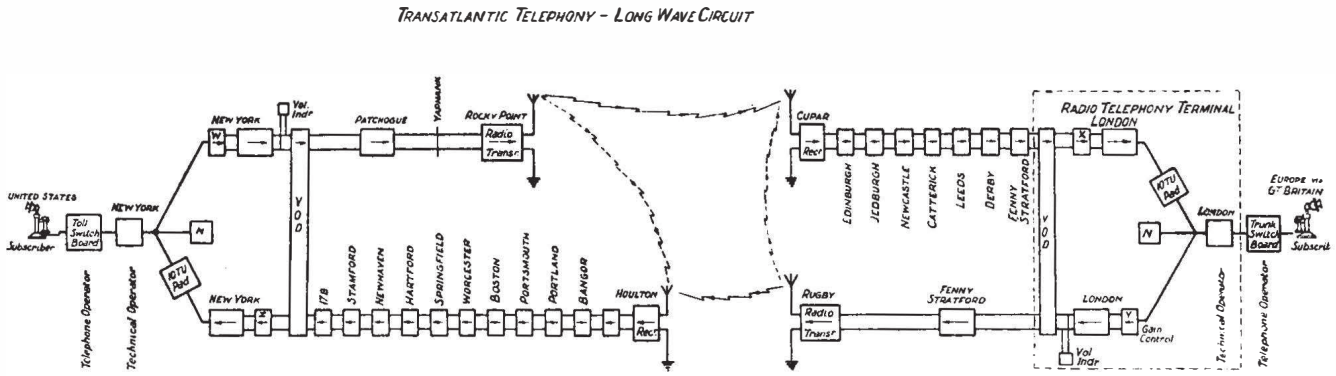


FIG. 1.

London to New York.

London operator.
London terminal position.
85 miles of land line to Rugby Transmitting Station.
2,900 miles of radio to Houlton (Maine) Receiving Station.
600 miles of land line to New York.
New York terminal position.
New York operator.

All the circuits are lined up between the 2-wire ends for a given loss of 10 dbs. in either direction, and it is, among other things, the duty of the Technical Operators to maintain, as far as possible, this standard of transmission for all types of talkers connected to the radio links. The radio transmitter must be loaded fully for each talker, as the percentage reduction in modulation at the transmitter due to a weak talker would seriously affect the grade of transmission at the distant point. The speech volume at the controlling terminal positions can be varied over a range of 30 decibels.

The terminal equipment consists essentially of a 4-wire hybrid termination, a variable control for the Transmitting and Receiving Repeaters and the Voice Operated Device. The voice operated device functions by means of the voice currents of the two telephone subscribers, in such a manner as to permit speech to pass first in one direction when one subscriber is talking and then in the opposite direction when the other subscriber talks. When no one is talking, the receiving path remains open to receive speech, whilst the transmitting path is inoperative.

The radio telephony terminal has been designed to accommodate twelve radio terminal positions arranged in pairs to occupy three sides of the room.

Fig. 2. The photograph shows the lay-out for two radio terminals excluding the voice operated devices. The racks are 10' 6" high and are the type normally used at Repeater Stations.

Bays 1, 2, 4 and 5 show the 4-wire termination for each channel and Bay 3 the testing equipment.

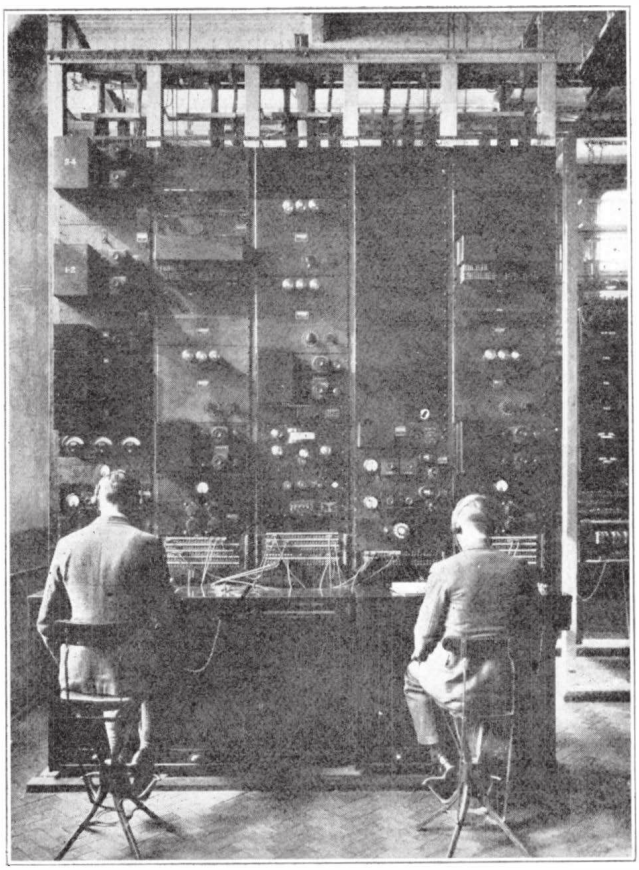


FIG. 2.—LAY-OUT OF FACE EQUIPMENT FOR TWO RADIO TERMINALS.

Immediately behind this rack, on five corresponding bays, are placed the voice operated device equipment for each channel. (See Fig. **2** (*a*)). For the purpose of describing the 4-wire termination for each channel, it is only necessary to refer to bays 1, 2 and 3.

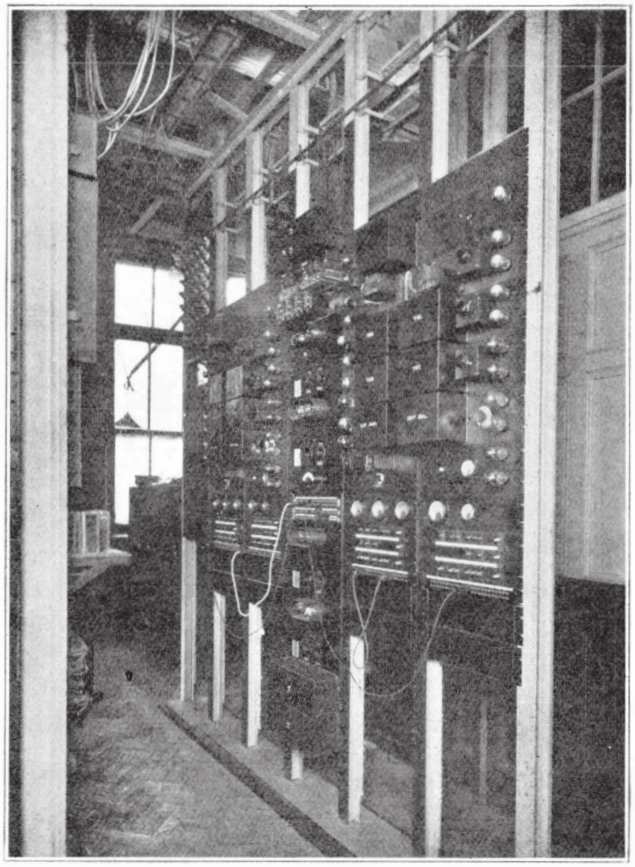


FIG. 2 (*a*).—VOICE OPERATED EQUIPMENT FOR TWO RADIO CIRCUITS.

Bay 1 contains the battery supply equipment and meter control for the various amplifiers; a dial for remote control of the receiving sensitivity of the voice operated device (dependent upon radio conditions); and a switch for varying the time hang-over of the voice operated device for given line echoes and transmission irregularities associated with the local subscribers connection.

In Bay 2 is arranged the operating equipment, consisting of the Radio jack field in which is terminated the radio circuit, gain control, volume indicator, regular transmitting and receiving amplifiers, hybrid termination (4-wire to 2-wire) monitoring control and a standard toll desk.

The standard toll desk is equipped with three sets of cords and associated keys, which permit the technical operator to talk on both front and back cords. The back cord is used for the 2-wire portion of the radio link and the front cord for connection to the trunk operator.

A telegraph key is mounted on the top of the desk for use in conjunction with an oscillator to key morse signals in lining up the circuits.

Fig. **3** shews the order of the jack field for the terminal connections, receiving and transmitting stations. The gain control for each repeater is in the form of a variable attenuator, which is in series with the terminal repeater having constant gain. It is specially constructed for variation in steps of 2.5 dbs. from zero to 30 dbs. In the case of the transmitting repeater, it may reduce the overall gain of the repeater unit by 5 dbs. for a strong talker, or increase it by 25 dbs. for a weak speaker. The control is varied in conjunction with the volume indicator connected at the output jack of the transmitting repeater to enable the technical operator to load fully the radio transmitter, and this is done by maintaining a constant speech current at this point in the system. It is therefore a means of checking the output from the terminal to the land line, which is assumed to have a constant transmission equivalent determined by the requirements of the radio transmitter. The volume indicator used for this purpose is a specially constructed thermionic valve voltmeter. It records a measure of rectified currents on a galvanometer in its plate circuit.

Reference speech volume is recorded when the galvanometer deflects between 5 and 25 divisions and approximately once to 30 divisions every 3 seconds. " Reference speech volume " is quite an arbitrary term, but for radio telephony purposes it corresponds to a speech volume which is 10 dbs. below the maximum distortionless speech output of a 4-wire repeater of the " standard " type, and is approximately the speech volume of an average male talker using a standard common battery instrument in circuit with a loop line resistance of 250 ohms. Adequate monitoring facilities are supplied to the traffic and technical operators at various points in the 4-wire links to check the operation of the terminal equipment.

Bay 3 accommodates reserve equipment and testing apparatus. In this bay is the 74006A Transmission Testing Set, which is not only

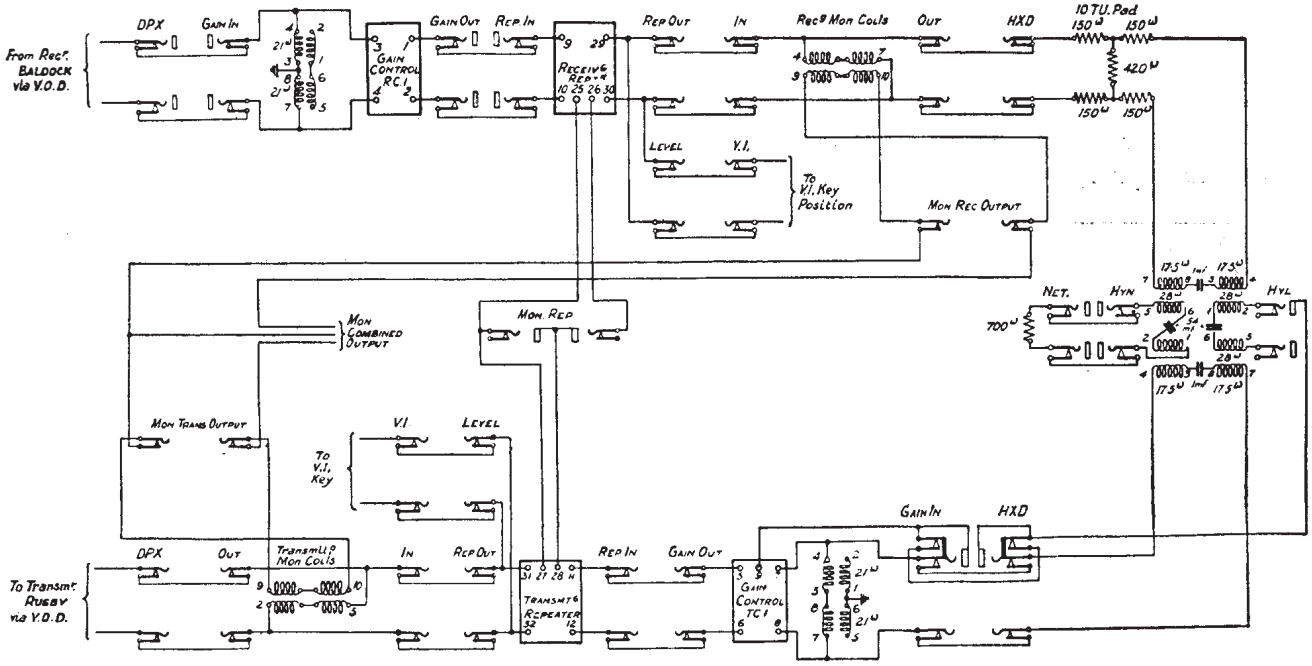


Fig. 3.—Marine Radio Telephony. Schematic of Regular Equipment.

used in conjunction with a 1500 cycle oscillator for lining up radio channels and wire lines, but is used for making half-hourly measurements of signal-to-noise ratio for recording the grade of service.

Voice Operated Devices. The reasons for the use of a voice operated device have been fully explained in an article by Messrs. C. A. Beer and G. T. Evans, which appeared in the *P.O.E.E. Journal* of April, 1927, dealing with the Long Wave Trans-Atlantic Telephony Channel. It is, however, desirable at this stage to state that a voice operated device is essential to the satisfactory operation of short wave channels, although the radio links may operate on different wavelengths: (1) To allow for independent terminal control without fear of singing conditions associated with the 4-wire link, and (2) To prevent reradiation of the received speech from either local transmitting station. If the latter were possible, eavesdroppers would only need to tune in to the local short wave station to enable them to listen to both sides of a conversation.

There are at present seven voice operated devices at the radio terminal, one of the American type, and six of the Post Office differential voice operated equipment.

As the Post Office equipment has been previously described in this journal it is only necessary to describe briefly the operations of the American Telephone and Telegraph Co.'s Voice Operated Device known as the " Vodas."

" *Vodas.*"—A schematic diagram of this device is shown in Fig. **4**, the transmitting side of which is normally made inoperative by means of a short-circuit of the transmitting path at Transmitting Singing Suppressor Relay (" TSS "), and " Auxiliary TSS." Before the transmitting path is opened the receiving side must be closed in a similar way. This is done by means of amplifier-detector units, which are bridged across the transmitting and receiving line respectively.

Speech passing from the local terminal to the radio transmitter must open a path for itself instantaneously; failing this, parts of speech would be lost or mutilated. An amplifier-detector and chain of relays can be made very sensitive to perform this operation. As most lines connected to the radio link possess a certain amount of line noise it is desirable that the amplifier-detector shall not be too sensitive, or the line noise would in many instances either lock up the chain of relays or cause false operations of the device. To partially overcome this difficulty, a delay circuit has been introduced between

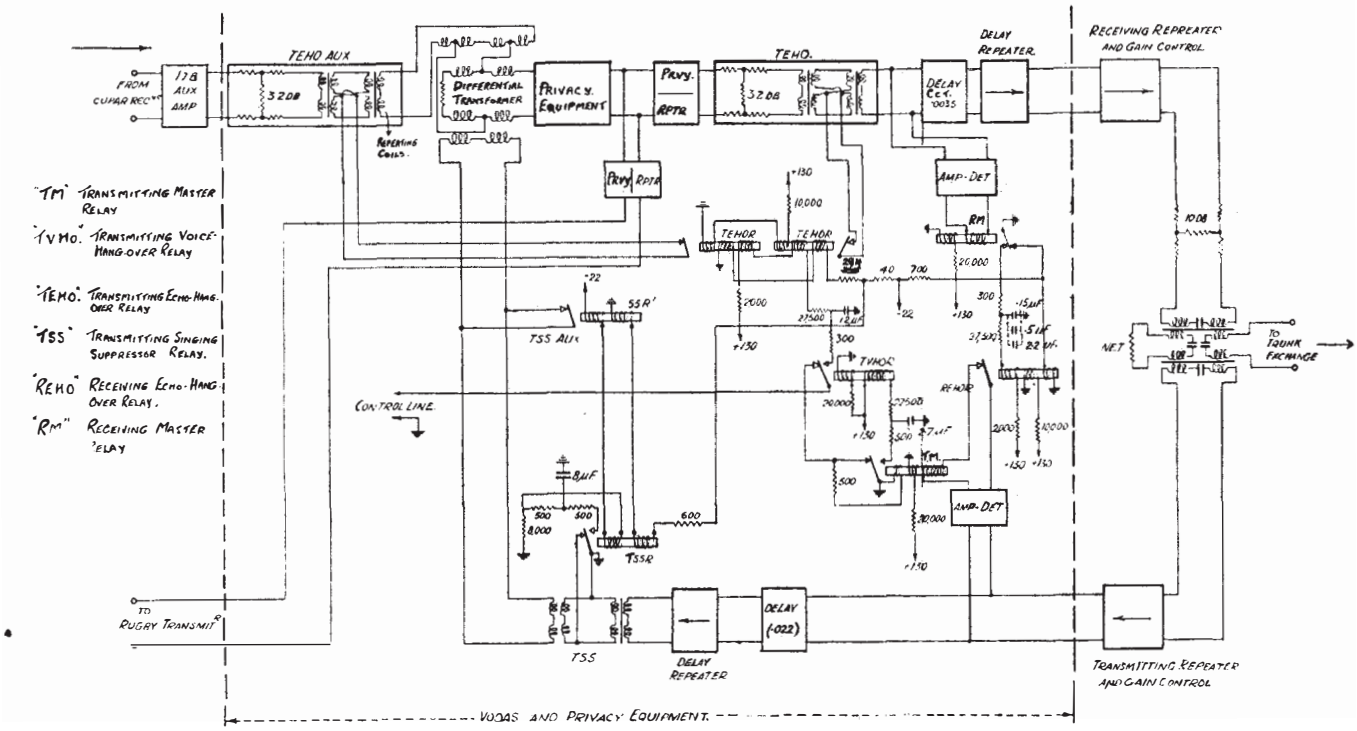


FIG. 4.—RADIO TERMINAL EQUIPMENT. SCHEMATIC OF "VODAS" WITH PRIVACY FACILITIES.

the junction where the amplifier-detector is bridged across the transmitting line and the point where the short-circuit is removed. This delay circuit of .022 second enables the sensitivity of the relay system to be reduced by approximately 10 db.

The receiving side of the device is normally open to receive speech. An amplifier detector is bridged across the line and operates a relay, the function of which is to cause the transmitting side of the device to be inoperative during the period the receiving side takes control of the speech transmission.

To ensure satisfactory operation it is essential that there should exist a ratio of signal-to-radio-noise, which will permit the amplifier detector to be operated by the incoming speech and not by radio noise. However, experience has indicated that a few false operations of the receiving side can be allowed without seriously affecting the service. The ideal arrangement is obviously a low background of radio noise which allows maximum sensitivity of the receiving amplifier-detector for all parts of speech. This sensitivity control is adjusted by the technical operator from time to time according to radio conditions.

Fig. 4 shows the essential parts of the "Vodas" together with facilities for inserting a privacy equipment when desired.

OPERATING DETAILS.

The device functions as follows:—

Receiving Side.—Speech from the radio receiver enters the receiving path *via* the Auxiliary receiving repeater, Auxiliary Transmitting Echo-Hangover (T.E.H.O.) Relay, repeating coils, differential transformer, privacy equipment, delay circuit, delay repeater, gain control, terminal repeater, and thence through a 10 db. pad to the hybrid termination and 2-wire line. Speech transmission to the radio transmitter is prevented by the short-circuit applied by the Aux. T.S.S. relay.

Before entering the receiving delay circuit a portion of the speech is passed to the receiving amplifier-detector unit and operates a master relay. The operation of this relay releases a 22-volt battery, which causes the Receiving Echo-Hang-over (R.E.H.O.) relay to operate; this in turn disconnects the plate circuit of the transmitting amplifier detector, thus preventing

any operation of the chain of relays associated with the transmitting side of the device.

Once the R.E.H.O. relays have operated, the release time of these relays is controlled by the charging of condensers through a resistance from the 130-volt battery supply. These condensers have been previously discharged by the earth contact of the Receiving Master relay armature. Hangover periods of .02, .04 and .11 seconds have been provided. The desired hangover, depending upon the transmission characteristics of the line connected to the circuit, is selected by means of a three-position key. All long distance lines are to a certain extent subject to impedance irregularities and experience has shown that transmitted currents pass along such lines and return to the terminal position with a definite time delay commonly termed " echo effects." For this reason it has been necessary to introduce a variable hangover to cause the transmitting side of the device to be inoperative for sufficient time to suppress such undesirable effects, which if not taken care of would cause mutilation of received speech due to false operations of the transmitting side.

Transmitting Side. — Speech entering the transmitting side, after passing through the hybrid termination, the transmitting gain control and terminal repeater, enters the transmitting amplifier-detector and operates the master Relay. The break contact of this relay removes an earth connection which allows the " T.E.H.O.," " AUX. T.E.H.O.," " T.S.S. " and " AUX. T.S.S." relays to operate, whilst its " make " contact operates the Voice hangover relay.

The T.S.S. and AUX. T.S.S. relays act as gates to open a path for the speech which has been traversing the delay circuit. The delay circuit is .022 second; as it takes .003 second for the chain of relays to operate there is therefore a clear margin of .019 second against initial clipping of the transmitted speech.

It will be observed that the armature of the Transmitting Voice Hangover (T.V.H.O.) relay must restore to its normal position before the T.S.S. and AUX. T.S.S. relays can again cause the transmitting path to be inoperative. The release of T.V.H.O. and T.E.H.O. relays is controlled by the charging of condensers of fixed value, in a similar manner to the R.E.H.O. relays associated with the receiving side of the device. After the transmitting master relay has restored to its normal position, the T.V.H.O. relay possesses a hangover of .15 second before it resumes its normal position, to prevent a closure of the transmitting path during the transit of weak syllables which may not operate the master relay.

When the armature of the T.V.H.O. returns to normal, a further delay of .04 second hangover is given to the T.E.H.O. relays to ensure that the receiving side remains closed for a sufficient time to cover the transmission delay over the land lines, *via* the local loop, London, Rugby and Cupar. This condition is essential in connection with the long wave circuit which operates on a common radio frequency for both transmitting and receiving paths.

There are two interesting features about this device which should be referred to. (1) A delay circuit is placed in the receiving path to prevent the transmission of speech across the hybrid termination during the operation of the receiving master relay before this relay makes the transmitting side inoperative. (2) To ensure rapid opening and closing of the receiving path, the armature of the T.E.H.O. relay is associated with repeating coils so arranged that when the armature is in the normal position the repeating coils have their centre terminals joined. Transmission from one coil to another is then quite normal, but when the relay armature is operated these centre contacts are disconnected and the respective coils are then in series in such a manner as to oppose one another, which prevents transmission from one coil to the other. By this means the time delay of the receiving delay circuit can be reduced, and gives the best possible balance conditions.

There are other interesting features associated with the equipment installed in the radio telephony terminal, but the main operations are covered by the foregoing description.

RADIO BEAMS.

T. WALMSLEY, B.Sc., M.I.C.E.

WITH the increasing complexity of engineering science and achievement a progressively greater degree of specialisation is demanded. In consequence, engineering must be divided into branches, and again divided and subdivided to enable the limited human comprehension to master imperfectly one small portion of the whole. Radio engineering, although perhaps the youngest branch of engineering, has advanced with such rapidity that few minds can grasp in detail all its complexities and ramifications. Still, the specialist in one branch can and should acquire a general acquaintance with the technical activities in another, and his task would be simplified if those who have devoted time to a close study of a subject would give a technical outline of their investigations. It is with this thought that the present article is penned. It is an effort to tell in terms that are not too highly technical, the activities of one branch of the Radio Section.

Principles of directive Aerials.—The principle of interference underlines the action of directive aerials. If A (Fig. 1) is a centre of energy

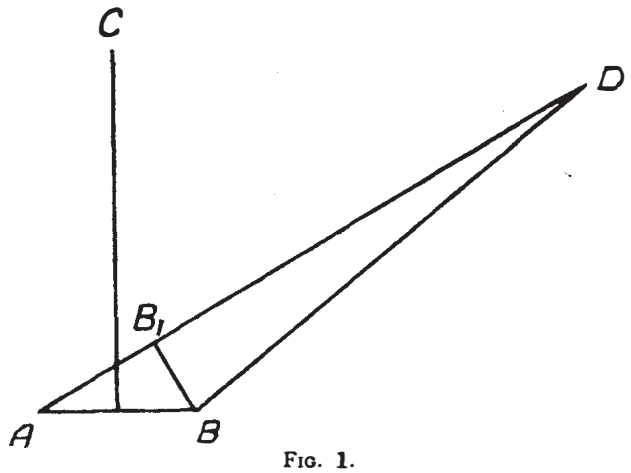


FIG. 1.

capable of imparting to a surrounding homogeneous medium some form of regularly timed pulsations, expanding spherical surfaces of energy will be radiated. For our present purpose, too close an enquiry into the nature of the impulses and the medium is not necessary; it is sufficient to picture wave after wave of energy passing outwards into space.

If now a second source of energy, located at B, gives rise to exactly similar pulsations as A, it is evident that the disturbance at any point in space will be affected by the energy radiated from both sources. All points, however, will not be similarly affected. For example, at the point C in the line drawn at right angles to AB, the disturbance due to both sources will be exactly the same amplitude, and if C be sufficiently far away to render the lines AC and BC sensibly perpendicular to AB, the resulting disturbance will be the simple arithmetic sum of the individual disturbances.

Another point D will experience quite a different influence to the point C. If, for example, A and B are supplied in phase with electric current having the same amplitude, and the spacing between A and B is such that the waves of energy emanating from each source arrive at D in exactly opposite phase, a cancellation effect will result.

If A and B are just half a wave-length apart, the location of D will obviously be on the lines BA and AB produced, and any other point, will experience an influence intermediate in amplitude to those at D and C.

Horizontal Polar Diagram.—It is thus possible to represent the amplitude of the disturbance—or the field strength—at any point on a circle around A and B by a closed figure, termed a polar diagram. Such a diagram is shown in Fig. 2.

The polar diagram for the two source system AB in which wires are spaced two wave-lengths apart is shown in Fig. 3. Lines drawn from the origin O of the diagram to the curve represent the relative amplitudes of the fields at great distances from the sources of energy.

The diagram of Fig. 3 presents such a marked difference to that of Fig. 2 that some explanation is necessary. It will be observed that at angles of 14.5° and 48.5° with the direction perpen-

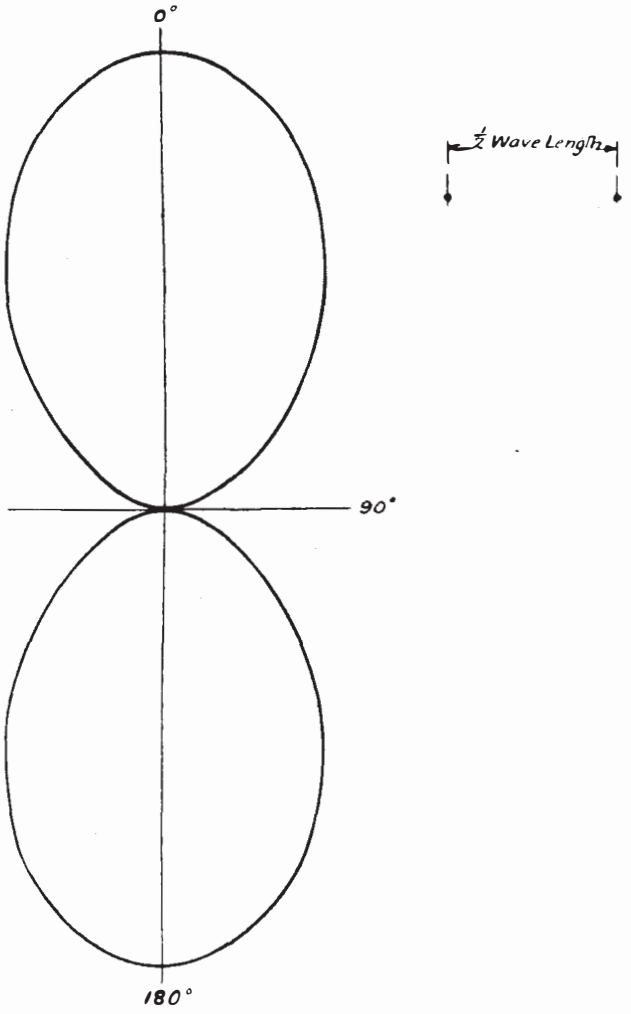


FIG. 2.—HORIZONTAL POLAR DIAGRAM DUE TO TWO VERTICAL SYNPHASED RADIATORS SPACED HALF A WAVE-LENGTH APART.

dicular to AB, the field strength falls to zero. The reason for this will be understood by referring to Fig. 1.

Disturbances from A and B are propagated simultaneously.

Suppose D is a point in space a great distance away from A and B, so that the two wave fronts at D due to the radiations practically coincide. The value of the existing field at any moment will be the instantaneous sum of the individual fields. If BB_1 is drawn perpendicular to AD, B_1D and BD are approximately the same length. Thus the disturbance at D due to B will have travelled farther than the disturbance due to A by the length AB_1. Now AB_1 is equal to half a wave-length when the angle ABB_1 is 14.5°, or 48.5° and thus in directions making these angles

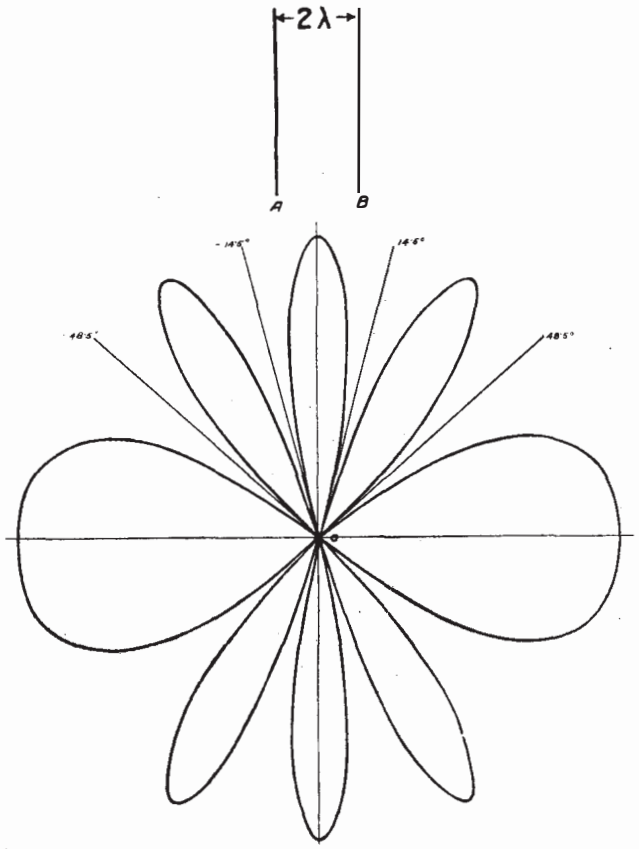


FIG. 3.—HORIZONTAL POLAR DIAGRAM DUE TO TWO SIMILAR VERTICAL SYNPHASED RADIATORS SPACED TWO WAVE-LENGTHS APART.

cancellation of electric fields will be experienced.

If, instead of two radiators spaced two wave-lengths apart, four radiators spaced half a wave-length apart were used, the horizontal polar diagram would be similar to Fig. 4. With this arrangement, there is a cancellation effect at 90°, with a maximum effect at 0° and 180°.

Heart Shaped Diagram.—It will be observed that in all the foregoing discussion, the polar diagrams due to a number of wires—or an "array"—have been derived from the polar diagram due to one radiator, namely, a circle. If instead of the circle as unit, it were possible to use a heart-shaped diagram—known also as a cardioid—such as that shown in Fig. 5, the polar diagram due to the combination of four systems having half a wave-length space separation would give the diagram shown in Fig. 6, which has been obtained by multiplying the values of Figs. 4 and 5 together, due regard being made to the appropriate directions.

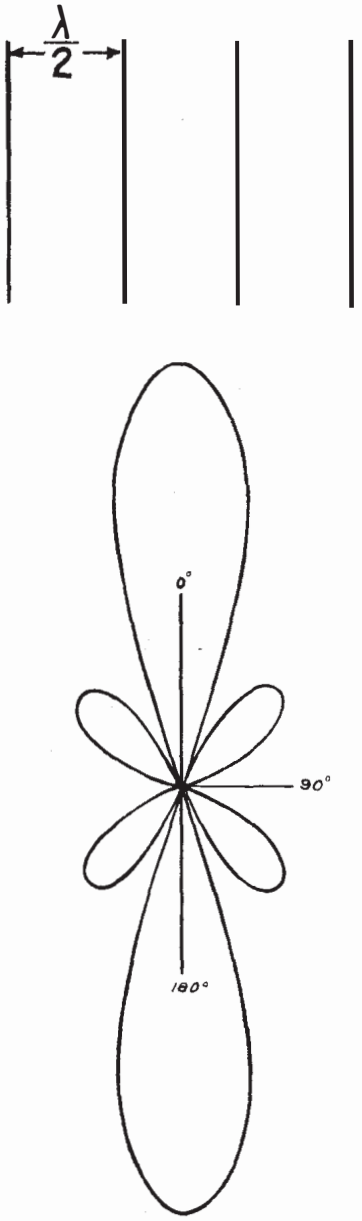


FIG. 4.—HORIZONTAL POLAR DIAGRAM DUE TO FOUR VERTICAL SYNPHASED RADIATORS SPACED HALF A WAVE-LENGTH APART.

A heart-shaped polar diagram is obtained by placing two exactly similar radiators one behind the other, at a distance of one quarter of a wave-length and feeding the radiators with current differing in phase by a quarter of a period.

Thus, in Fig. 5, if the current in radiator B lags 90° behind the current in A the fields due to the two radiators will add arithmetically in the direction AB and will cancel out in the direction BA. In other directions, the resultant field will have same value, intermediate between the two extremes.

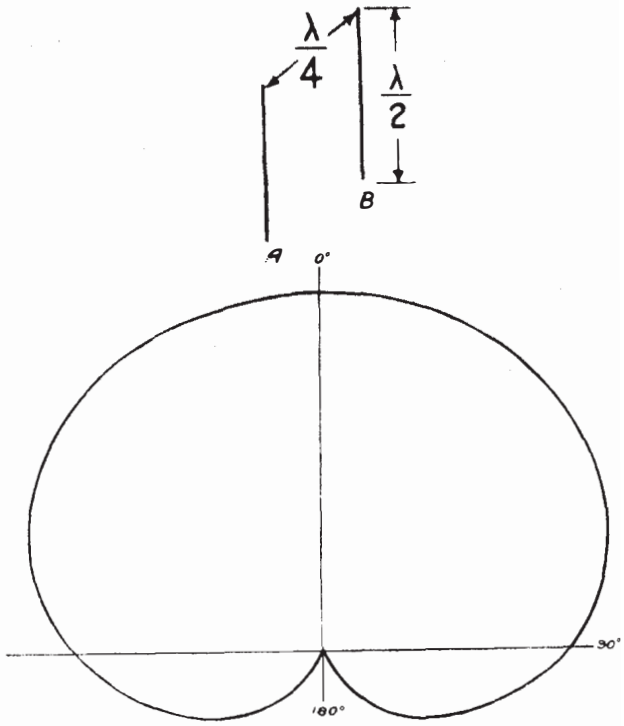


FIG. 5.—HORIZONTAL DIAGRAM DUE TO TWO SIMILAR RADIATORS SPACED A QUARTER OF A WAVE-LENGTH APART AND CURRENTS DIFFERING 90° IN PHASE.

Combining Cardioids to form a "Beam."—A "beam" aerial therefore can be built by grouping a number of cardioid producing units in a

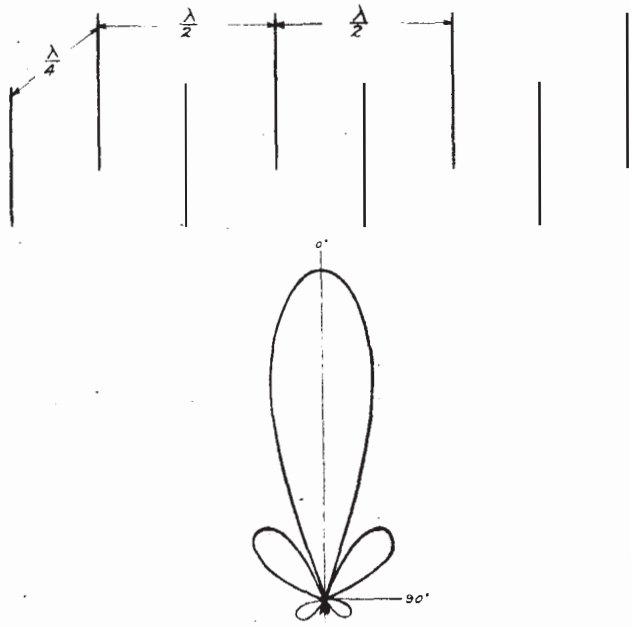


FIG. 6.—HORIZONTAL POLAR DIAGRAM DUE TO FOUR SYSTEMS SIMILAR TO FIG. 5 SPACED HALF A WAVE-LENGTH BETWEEN ADJACENT GROUPS.

line. Frequently a separation of half a wave is allowed between adjacent wires, and spans of 500 feet between extreme wires are common.

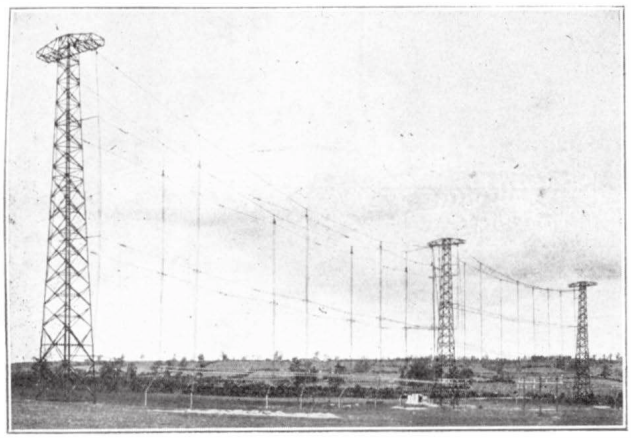


Fig. 7.—A Beam Aerial Array.

A " beam " aerial thus usually consists of two curtains of radiators, the distance between curtains being about one quarter of a wave-length. The wires of the front curtain are fed with currents all in phase, whilst the wires in the back curtain have currents in phase with each other, but 90° out of phase with the currents in the front curtain. The back curtain may be fed directly, but a more usual method is to be fed inductively. In this method, the back curtain is entirely insulated from any source of supply and reliance is placed upon the currents induced in it by the field due to the front curtain. A practical example of such a beam is shown in Fig. **7** which depicts a " beam " array supported on 180 feet self-supporting towers.

Vertical Polar Diagrams. — So far only horizontal polar diagrams have been considered, but it is obvious that the same principles just considered can be applied to polar diagrams in the vertical plane. Consider an insulated vertical wire radiator having a length equal to half a wave and its lower end at ground level. It can be shown that the field distribution due to such a radiator in a vertical plane is represented by the diagram shown in Fig. **8**. The combination of two such synphased radiators, spaced two wave-lengths apart, gives rise to the diagram shown in Fig. **9**, which is obtained from the diagrams of Figs. **3** and **8** by simple multiplication.

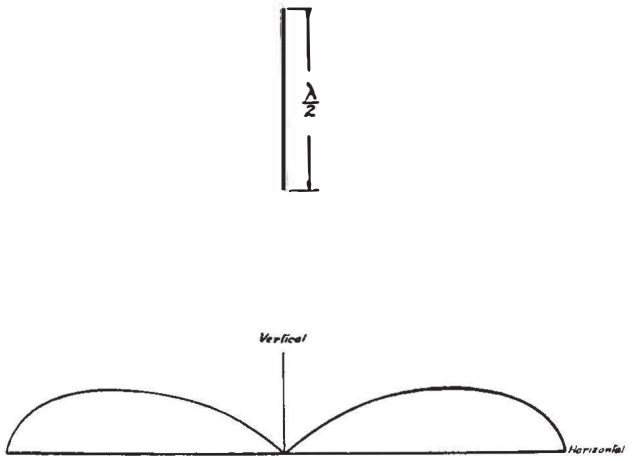


Fig. 8.—Polar Diagram in a Vertical Plane due to an Insulated Vertical Half Wave Radiator having its Lower End at Ground Level.

" Sharpening " of the vertical polar diagram can also be obtained by building radiators one on top of the other, but the cost of the necessary supporting structures quickly limits the economic usefulness of this method.

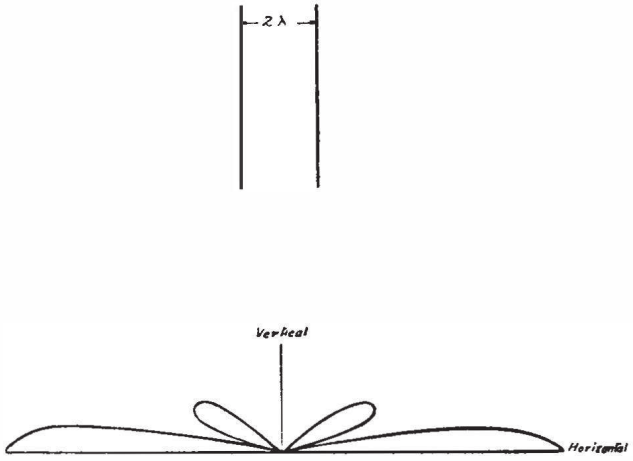


Fig. 9.—Polar Diagram in a Vertical Plane normal to the Plane containing two Synphased Vertical Radiators described in Fig. 8.

It seems hardly necessary to stress the fact that the primary object in designing " beam " arrays is to seek to direct a maximum amount of power in a desired direction and eliminate unwanted radiation in other directions, due regard being made to the economics of the question.

A SIDELIGHT ON THE EARLY HISTORY OF THE TELEPHONE.

THE name of Mr. George Bernard Shaw is known wherever the English language is read or translated, but the fact that he was at one time closely associated with the telephone business must come as news to most people. Our attention having been directed to the preface of an early novel by Mr. Shaw, "The Irrational Knot," we thought our readers would be interested in the matter. As, however, we considered it advisable first to obtain his consent to publish an extract from the preface, the following correspondence took place:—

22nd December, 1930.

George Bernard Shaw, Esq.,

.....

Dear Sir,

The revelation in your preface to "The Irrational Knot" that you were a pioneer of the telephone in London is so important that I would be grateful to have your permission to publish an extract from that preface in *The Post Office Electrical Engineers' Journal.*

The passages we wish to quote are those beginning "This book is not wholly a compound of intuition and ignorance," and down to ". . . . . a question they either decided in the negative or never decided at all, for I never got anything."

Telephone engineers all over the world will be honoured to learn that they may claim you as a colleague and this Journal will undertake to defend you from any possible imputation that the British Telephone Service, in spite of the advantages of Government control, has never recovered from your association with it in 1879.

I am sending you separately a copy of the Journal, a glance at which may indicate its character to you. Remarkable as it may seem, this magazine, which circulates all over the world, is written by engineers who are paid nothing for their contributions. If you agree to allow us to publish the foregoing extract, we regret that we are not able to offer more than our usual terms.

Yours faithfully,
W. CRUICKSHANK,
Managing Editor.

30th December, 1930.

Dear Sir,

In reply to your letter of the 22nd inst., Mr. Bernard Shaw desires me to say that you are quite welcome to quote from the preface to "The Irrational Knot," but you must not represent him as presuming to pretend that he was an electrical engineer. He organized the wayleave department, but never learnt the difference between an Ohm and an Amp.

Yours faithfully,
BLANCHE PATCH,
Secretary.

W. Cruickshank, Esq.

The extract is as follows:—

Extract from the preface to "The Irrational Knot," a novel, by George Bernard Shaw.

"This book is not wholly a compound of intuition and ignorance. Take for example the profession of my hero, an Irish-American engineer. That was by no means a flight of fancy. For you must not suppose that, because I am a man of letters, I never tried to earn an honest living. I began trying to commit that sin against my nature when I was fifteen, and persevered, from youthful timidity and diffidence, until I was twenty-three. My last attempt was in 1879, when a Company was formed in London to exploit an ingenious invention by Mr. Thomas Alva Edison—a much too ingenious invention as it proved, being nothing less than a telephone of such stentorian efficiency that it bellowed your most private communications all over the house instead of whispering them with some sort of discretion. This was not what the British stockbroker wanted; so the Company was soon merged in the National Telephone Company, after making a place for itself in the history of literature, quite unintentionally, by providing me with a job. Whilst the Edison Telephone Company lasted, it crowded the basement of a high pile of offices in Queen Victoria Street with American artificers. These deluded and romantic men gave me a glimpse of the skilled proletariat of the United States. They sang obsolete sentimental songs with genuine emotion; and their language was frightful even to an Irishman. They worked with a ferocious energy which was out of all proportion to the actual result achieved. Indomitably resolved to assert their republican manhood by taking no orders from a tall-hatted Englishman, whose stiff politeness covered his conviction that they were, relatively to himself, inferior and common persons, they insisted on being slave-driven with genuine American oaths by a genuine free and equal American foreman. They utterly despised the artfully slow British workman who did as little for his wages as he possibly could; never hurried himself; and had a deep reverence for any one whose pocket could be tapped by respectful behaviour. Need I add that they were contemptuously wondered at by this same British workman as a parcel of outlandish adult boys, who sweated themselves for their employer's benefit instead of looking after their own interests? They adored Mr. Edison as the greatest man of all time in every possible department of science, art and philosophy, and execrated Mr. Graham Bell, the inventor of the rival telephone, as his Satanic adversary; but each of them had (or intended to have) on the brink of completion an improvement on the telephone, generally a new transmitter. They were free-souled creatures, excellent company, sensitive, cheerful and profane; liars, braggarts and hustlers; with the air of making slow old England hum which never left them even when, as often happened, they were wrestling with difficulties of their own making, or struggling in no-thoroughfares from which they had to be retrieved like stray sheep by Englishmen without imagination enough to go wrong.

In this environment I remained for some months. As I was interested in physics, and had read Tyndall and Helmholtz, besides having learnt something in Ireland through a fortunate friendship with a cousin of Mr. Graham Bell, who was also a chemist and physicist, I was, I believe, the only person in the entire establishment who knew the current scientific explanation of telephony; and as I struck up a friendship with our official lecturer—a Colchester man whose strong point was pre-scientific agriculture, I often discharged his duties for him in a manner which, I am persuaded, laid the foundation of Mr. Edison's London reputation; my sole reward being my boyish delight in the half-concealed incredulity of our visitors (who were convinced by the hoarsely startling utterances of the telephone that the speaker, alleged by me to be twenty miles away, was really using a speaking trumpet in the next room), and their obvious uncertainty, when the demonstration was over, as to whether they ought to tip me or not; a question they either decided in the negative or never decided at all, for I never got anything."

The following information has been sent to us from the Office of the High Commissioner of Canada:—

TRANS-CANADA TELEPHONE LINES.

Alberta Section to be Completed.

The Alberta Department of Railways and Telephones is to spend £90,000 during the current year on the completion of the section in that province of the trans-Canada telephone line. The amount named will cover the construction of 160 miles of line from Strathmore easterly to the Saskatchewan boundary.

Work carried on in 1930 in connection with the all-Canada route cost about £90,000. In some cases lines already in use were brought up to the higher standard of efficiency set for the coast-to-coast line.

The trans-Canada telephone line is expected to be in operation by the end of 1931, and when completed will obviate the necessity of routing calls through the United States at certain points. Eight of the telephone companies or governmental telephone systems are co-operating to provide the through circuit which will make conversation possible between Halifax and Vancouver by an all-Canadian route. The systems in question are those of the Maritime Telephone and Telegraph Company, the New Brunswick Telephone Company, the Bell Telephone Company of Canada, the Manitoba Government Telephone System, the Saskatchewan Government Telephone System, the Alberta Government Telephone System and the British Columbia Telephone Company.

It was announced recently in Vancouver that the British Columbia Telephone Company had started the construction of that section of the trans-Canada line passing through the Pacific Province. The British Columbia link will cost £250,000, involving the installation of 655 miles of telephone line, of which 125 miles have already been built. The British Columbia link is to connect with the line being built by the Alberta Government telephone system through the Crow's Nest Pass, the line passing by way of Macleod, Calgary, Medicine Hat and onwards to the Saskatchewan boundary. In eastern Canada much work has been done during the past few years in preparation for the trans-Canada service, and in Montreal recently representatives of the eight operating systems met at a special maintenance school conducted by the Bell Telephone Company of Canada to study problems connected with the operation of this new 4,000-mile line.

TELEPHONE DEVELOPMENT IN CANADA.

Continued expansion of the Bell Telephone System.

The Bell Telephone Company of Canada, Ltd., the largest of the telephone systems operating in the Dominion, intends to spend £4,000,000 on development during 1931. The Company, which operates exclusively in the provinces of Ontario and Quebec, has during the past five years invested no less than £24,000,000.

The major portion of the 1931 appropriation will be spent on the improvement of existing telephone facilities, although there will be plans for certain necessary extensions. Central office equipment will cost upwards of £1,000,000; long distance (outside plant) about £550,000; exchange lines nearly £1,000,000; land and buildings £200,000; and subscribers' station equipment over £1,000,000. The Company will continue to carry out the conversion of its urban systems from manual to automatic services. In Montreal, Toronto, Hamilton, Quebec and Windsor—five of the leading cities served by the Company—there has been a continuous installation of dial switching apparatus.

Major extension projects contemplated for 1931 include the rebuilding of one of the main lines between Montreal and Toronto costing about £130,000. "Carrier" equipment is to be added to the long distance line from Oshawa to Winnipeg in order to provide additional talking channels to points in western Canada.

The Secretary of the I.P.O.E.E. has sent us two interesting documents of an earlier telegraph age—one, General Order, No. 121, of the U.K. Electric Telegraph Coy., Ltd., issued from the Secretary's Office, 537, Gresham House, Old Broad Street, on 16th July, 1866; and the other, Folio No. 40, 1872 (an early edition of the P.O. Circular) in which appears a list of promotions and appointments in the Engineering Department. The General Order gives instructions upon the adjustment of the Siemens Relay, the

Morse Inker and Keys, and explains the treatment to be applied in dealing with Split and Failing Currents, Occasional Failing of Current in an Instrument and Permanent Local Currents in Relay Instruments. The Folio mentions Mr. R. S. Culley as Engineer-in-Chief, one Assistant Engineer-in-Chief, one Electrician and Submarine Superintendent, two Chief Clerks (Mr. J. Hookey is one), three Clerks 1st Class and 11 Clerks (General Body), among whom we observe the names of Messrs. J. B. Chapman, J. Willmot and A. F. Varley. There were six Divisional Engineers, one being Mr. W. H. Preece, and two Superintending Engineers for London. Seven Superintendents First Class are given and 23 Second Class, including Messrs. J. Gavey in the Southern Division and A. W. Heaviside, Northern. Mr. A. Bell is Superintendent of Factories and Mr. J. Shaw Superintendent of Bolton Factory. Among the Special Staff is a Controller of Special Arrangements and Supervisor of Schools; Mr. M. Cooper is an Assistant Superintendent on this staff. The Folio concludes with the following items:—

Dismissals.

Telegraphist. . . . . for making use of disgusting language on the wires.

Telegraphist. . . . . for insubordination.

In the *Electrical Review* of the 30th January the death is recorded of Col. H. Laws Webb, which occurred on the 19th of the month. The Colonel, then well-known in the telephone world as Mr. Laws Webb, was a redoubtable protagonist of private enterprise in telephony before the transfer, and contributed numerous articles to the press both on the technical and service sides. He negotiated a concession for telephones with the Turkish Government and had been a director of the Constantinople Telephone Co. since its formation. He joined the R.A.F. during the war and was employed on communications, attaining the rank of Lieut.-Colonel.

The many friends of Mr. J. R. Andrews, formerly Executive Engineer, Newcastle-on-Tyne, and Chairman of the Freemen of that City, will be pleased to hear that he has been appointed a Justice of the Peace.

Mr. Jupp, of the Test Section, has sent us the following cutting from "Standard Topics." He adds, "If the method were ever required here, the most difficult operation would be to catch the rat!

RATS!

If we were not confident that we can rely upon the absolute veracity of our correspondent, we might be inclined to doubt this story, which has been forwarded to us from Italy by C. S. Briggs, General Manufacturing Department.

Not a "Standard" Process.

"The other day I chanced to hear of a highly original and amusing method of pulling a drawing-in wire into a telephone duct. In fact, I thought it too good to lapse into obscurity, and I am here giving it the publicity that I think it deserves.

It appears that an empty duct in Turin had defied all efforts to pull into it the usual drawing-in wire preparatory to pulling in the cable. All approved methods had been tried and tried again, but yet the necessary connection could not be made. At last one of the gang came forward with a very original scheme. He, it appears, had caught a water rat, and his idea was to tie a string to the rat and then persuade it to run down the duct, thereby taking the string to the far end. Amidst much laughter it was decided to give this method a chance. The rat was produced, the string was attached to the thoroughly frightened animal who, encouraged by a blow-lamp flame, ran as fast as his legs could carry him to the other end of the duct, dragging the end of the string with him. As a reward for this invaluable service the rat was given his freedom, which I think no rat had ever more richly deserved."

The following errors, we regret to state, appeared in Vol. 23, Part 4, Jan., 1931:—

p. 306. Fig. 12. Attenuation Frequency Characteristics of Super-phantoms. Completed Cable.

Fig. 13. Impedance Frequency Characteristics of Super-phantoms. Completed Cable.

p. 307. Table 2. R (ohms loop) Side circuit, 21.8. Phantom Circuit, 10.68.

HEADQUARTER'S NOTES.

EXCHANGE EQUIPMENT.

The following works have been completed:—

Exchange.	Type.	No. of Lines
Livingstone	New Auto.	3000
Macaulay	,,	4500
Pollards	,,	4000
Gladstone	,,	4900
Rhos	,,	900
Ashton-on-Ribble	,,	550
Leyland	,,	420
Oxford	Auto Extn.	340
Brierley Hill	,,	Access Equipment
Nottingham	,,	190
Western Park	,,	300
Walsall	,,	Modifications
Arkwright	,,	Routiner Equipment
Sherwood	,,	Routiner Equipment
Rochdale	,,	Modifications
Ilford	,,	Excess Fee Metering
Western (London)	,,	Modifications
Mitcham	,,	Excess Fee Metering
Beckenham	,,	Excess Fee Metering
Mansfield	,,	Observation Equipment
Worthing	New Manual	3460
Morecambe	,,	1080
Chester	Manual Extn.	520
Bristol Motors	P.A.B.X.	20
Taunton Corporation	,,	20
Shell Mex (Belfast)	,,	20

Orders have been placed for the following works:—

Exchange.	Type.	No. of Lines
Pendleton	New Auto.	1620
Selly Oak	,,	1230
Abbeyhill	,,	540
Bayswater	,,	4600
Manchester Optg. School ...	,,	Positions
Colindale	,,	1940
Ashton-under-Lyne	,,	1700
Gately	,,	1400
Mayfair	,,	8550
Regent	,,	6700
Langham	,,	3300
Grosvenor	,,	2700
Tulse Hill	,,	6400
Ashfield	,,	400
Sunderland	,,	3900
Boldon	,,	500
Bishopwearmouth	,,	400
Woodgate	,,	400
Main (Oldham)	,,	3430
Headingly	Auto Extns.	400
Armley	,,	240
Clerkenwell	,,	Key sending
National	,,	Key sending
Darlington	,,	700
Edinburgh Central	,,	1740
Amherst	,,	100
Sherwood	,,	Routiner Equipment
High Wycombe	New Manual	2000
Orpington	,,	1700
Chislehurst	,,	1300
Seven Kings	,,	3000
Brentwood	,,	1800
Hastings	Manual Extn.	Observation Equipment
Northampton	,,	Observation Equipment
Bournemouth	,,	Observation Equipment
Yorkshire Penny Post	P.A.B.X.	30
Maggs & Cory	,,	30
Wolverhampton Corpn. ...	,,	20
London Tfm. Service	,,	620
King & Hutchings	,,	30

WANTED for Japan a competent telephone engineer knowing particularly Strowger System, having extended practical experience on installation and maintenance work. For further information apply to BARNAY, 27 Rue des Balkans, Paris (20ème) France.

OXFORD UNIVERSITY.

SUMMER COURSE FOR ENGINEERING TEACHERS AT MERTON COLLEGE.

A NEW step in the education of Post Office Engineers was taken in the summer of last year when, by arrangement with the Board of Education, a number of officers of the Engineering Department devoted a portion of their annual leave to attending a course of training at Merton College.

The course was intended for teachers engaged in teaching Engineering Subjects, the primary aim being to consider the most suitable means of presenting to students certain of the subjects taught in the National Certificate course and the City and Guilds of London Institute grouped course in Telephony and Telegraphy, also to review recent advances in Engineering and Electrical Science and practice.

The Officers attending the course were selected from those engaged in teaching at Technical Colleges and Polytechnics in England and Wales. Twelve members of the Post Office staff attended, in company with about 50 others, most of whom were teachers by profession.

The Course consisted of lectures, demonstrations and discussions. The first lecture each day was devoted to either Telegraphy or Telephony and was given by a recognised authority in the particular aspect of the art dealt with. The second lecture was of a more general nature, but had reference to subjects bearing directly on Telephony and other forms of electrical communication, such as the presentation of the elements of Electricity and Magnetism, Units and Dimensions, also the Thermionic Valve and its applications in the practice of measurement and other related topics.

The lecturers included Dr. Chapman, H.M.I., Prof. C. L. Fortescue, M.A., Mr. E. W. B. Gill, M.A., Mr. A. C. Jolly, Prof. E. Mallett, D.Sc., Prof. E. W. Marchant, D.Sc., Mr. E. B. Moullin, M.A., and Mr. G. F. O'dell, B.Sc.

Discussions followed these lectures. A considerable portion of the time spent in the "Telephony" discussions was devoted to the present City and Guilds syllabus,—the general opinion of those attending these discussions being that the syllabus required some modification, but concrete proposals for such modifications were not advanced. The writers, however, consider it very desirable that each year's syllabus should contain a preamble setting out the standard of knowledge which it is hoped the students will have attained at the end of the year. It transpired during these discussions that the advantages of the grouped course scheme are not sufficiently well understood by teachers or explained to the students at the time of enrolment, with the result that students often receive only partial instruction instead of the comprehensive training intended.

For the purpose of these discussions the members of the Course were divided into small groups and the discussions took place in the Tutors' rooms, where the expressions of opinions were stimulated by the congenial atmosphere that prevailed.

The final lectures of the day were given after dinner by eminent educationalists. The following list indicates the diversity of the subjects dealt with:—

"The Development of Thought"—Mr. A. S. Barnes, the Chairman of the Course.

"Recent Research on the Design of Airships"—Prof. Southwell, University of Oxford.

"Science and Engineering"—Prof. F. C. Lea, D.Sc., Sheffield University.

"The Science Museum"—Sir Henry Lyon, Director of the Science Museum, South Kensington.

"Plasticity and Flow of Metals"—Prof. B. P. Haigh, Royal Naval College, Greenwich.

"Teaching of Engineering History"—Mr. L. Pendred, President, Inst. Mech. Engineers.

"The Practical Training of Students"—Sir Henry Fowler, Chief Engineer, L.M.S. Railway.

"Electrical and Mechanical Resonance"—Prof. C. L. Fortescue, Imperial College of Science and Technology.

Each of the lectures was followed by a keen and stimulating discussion.

A library of about 400 volumes of recent books dealing with Science, Engineering and Educa-

tion was available in the College for the use of the members.

Another feature was a lecture by Mr. Moullin on " Laboratory Work "; this was followed by a visit to the Electrical Engineering Laboratories of the University, which were in the process of being equipped.

All members of the Course resided in the rooms of the College normally occupied by the undergraduates, and this provided opportunities for social intercourse and discussions which frequently continued into the small hours.

Mr. E. H. Shaughnessy, O.B.E., M.I.E.E., and Col. Lee, B.Sc., M.I.E.E., visited the College during the course and took part in various discussions, both formal and informal, and we feel sure that they appreciated to the full the opportunities mentioned in the previous paragraph.

All meals were taken in the Dining Hall of the College. This Hall is the finest in Oxford, the walls and doorway having been built in the time of Walter De Merton, the Founder. Merton College has the honour of being the oldest in Oxford, and in it the real idea of a College is first found. Its statutes date back in the earliest to 1264 and are the models of other foundations both in Oxford and Cambridge. The College buildings may not claim to be the most beautiful, but are undoubtedly the most interesting in the University. The oldest portions are quite a century older than any other existing College building in Oxford and still preserve in many parts their original form.

Facilities for cricket, tennis, golf and swimming were provided, but the inclement weather prevented advantage being taken of these, with the result that our recreation consisted of visits to Colleges and other places of interest. The members of the Course familiar with Automatic Telephony conducted, by kind permission of Capt. Harris, the Sectional Engineer, the remaining members of the Course over Oxford Automatic Exchange.

The Chaplain of the College was good enough to conduct a special service in the College Chapel, which was attended by the staff and members.

The success of the Course as a whole owed much to the genial personality of the Chairman, Mr. A. S. Barnes, and the untiring work of the organising Secretary, Mr. Hartas Jackson, H.M.I. The Electrical Communications section was in the hands of Dr. Chapman, H.M.I., and to his enthusiastic and unselfish efforts the undoubted success of this part of the Course was due.

In conclusion, the writers would like to express their heartfelt appreciation of the lectures, discussions and intimate association with Tutors and Professors which they enjoyed during their residence in college. The experience, the expositions and the instruction received cannot but be of lasting benefit to all those who attended.

H. G. S. Peck.
C. W. Brown.

DISTRICT NOTES.

LONDON DISTRICT.

Growth of Telephone System.—The nett increases in the number of exchange lines and stations during the quarter ended 31st December, 1930, were 6,603 and 10,793 respectively.

New Trunk Cable—London to Brighton.—Preparations are being made for the provision of a new cable to Brighton which will be of unusual type. It will contain 74 pairs of wires in star quad formation and the weight of the conductors will be 10 lbs. per mile. The overall diameter will be 0.8 inch. The cable will be drawn into ducts through the London District, but from Coulsdon onwards the cable will be suspended on existing poles.

In normal circumstances a trunk cable containing so many conductors requires a separate duct and there is not always a spare duct available. In this case there is no spare duct over a large portion of the route, but owing to the small diameter of this special cable it is possible to find

space in partly occupied ducts and thus the time required to provide additional ducts will be eliminated. On account of its light weight, the cable will be attached to existing poles on the open route. The total time required to provide the cable will therefore be shortened by several months, as compared with the type of trunk cable which has hitherto been provided. Repeaters will be provided at Crawley, *i.e.*, about midway to Brighton. The cable will be utilised to provide 37 four-wire circuits.

Extension of Tandem Exchange.—The growth of traffic and the increase in the number of exchanges has necessitated a further extension of the main Tandem Exchange.

The equipment is being installed by the A.T.M. Co. to the Engineer-in-Chief's specification, and consists of additions to the cabling from I.D.F. to Test Jack Frame with increased accommodation thereon, C.C.I. and " Auto to Auto " repeaters, First Tandem Selectors and boards, and Third Code and Tandem Selectors and boards. Code Selectors are available to traffic from manual, and Tandem Selectors to traffic from auto exchanges only.

The London District is responsible for the regrading required to bring the new equipment into use, and considerable work will be involved.

The following brief summary shows the increase in capacity of the exchange produced by the extension :—

	Before Extension.	*After Extension.*
Maximum Number of junctions I/C from Manual Exchanges	2680	2880
Maximum Number of junctions I/C from Auto. Exchanges	2400	2880
Maximum Number of junctions O/G from Tandem	6400	9400
Total Number of Selectors (10 contact)	10838	13543
Total Number of Selectors (20 contact)	400	1600

New Automatic Exchanges.—Gulliver exchange was opened on January 1st, 1931, with 1,300 subscribers transferred from Hampstead. This exchange has an initial capacity of 4,400 lines and an ultimate capacity of 10,000 lines.

Pollards exchange was opened on February 4th with the transfer of 1,736 subscribers from the Pollards manual exchange, which was a C.B. 20 exchange installed as a temporary measure some years ago in the same building. The initial capacity of the auto exchange is 4,000 lines and the ultimate capacity 10,000 lines.

Both the above automatic exchanges were installed by Messrs. Siemens Bros. & Co.

Until Saturday, November 17th, the Hendon and Colindale automatic satellite exchanges were based on Maida Vale as a parent. On the above date they were transferred without hitch to a parent exchange at Gladstone. Over 900 lines were involved in this transfer, including all manual board circuits between the parent and satellites, Keysender " B " junctions and miscellaneous circuits. When the Gladstone Exchange was opened it dealt with the satellite traffic only, but on January 17th this was added to by the transfer of 2,300 lines from Willesden and Hampstead Exchanges. The Gladstone Exchange was equipped by Messrs. Ericsson and has an initial equipment of 5,100 lines. The ultimate capacity is 10,000 lines.

Work is proceeding on the equipment of the following new automatic exchanges :—

Prospect (Barnes).	Acorn (Acton).
Hampstead.	Southall.
Leytonstone.	Perivale.

The manual work for Southall and Perivale will be concentrated at Acorn and it is expected that appreciable economy will thereby be effected.

Progress is being made with the provision of a sub-tandem exchange in the Reliance building. This will be followed by other sub-tandem exchanges as the need arises. The object of these exchanges is to relieve the main Tandem exchange of the short distance indirect traffic.

Closing of Manual Exchanges.—The Kelvin manual exchange has been entirely freed by the transfer of the remaining lines to the Western Auto exchange and the manual equipment is being recovered for use elsewhere.

The Frobisher manual exchange is also being recovered in consequence of the transfer of the lines to the Frobisher automatic exchange, which is hypothetical on the Flaxman Exchange. This will result in the evacuation of the building in the Cromwell Road which was originally known as the Western Exchange and was one of the oldest C.B. exchanges in London.

Automatic Registration of Excess Fees.—Apparatus has been installed at the Mitcham

and Ilford Exchanges for the automatic registration of fees in excess of the unit fee.

New Manual Exchanges.—The installation of new manual exchanges at Ewell and Downland (Coulsdon) has commenced and also the new operators' training school at the Terminus Exchange building (King's Cross).

New Buildings.—New buildings for automatic exchanges are being erected at Plashet (Plaistow), Byron (S. Harrow), Hither Green, Bayswater, Merton, Tulse Hill, Mayfair, Colindale, Bowes Park, Bethnal Green, Kensington and others are about to be commenced. New buildings for manual exchanges are being erected at Sanderstead, Seven Kings, Chislehurst, Pinner, Epsom and Purley.

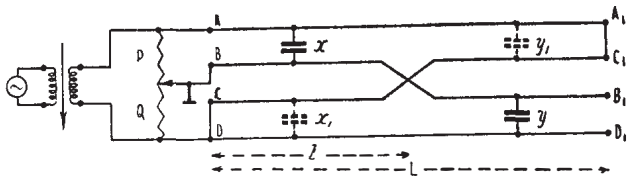
Fire Alarm System.—A Gamewell Fire Alarm System is being installed by the Standard Cables and Telephone Company for the L.C.C. in the Southwark Area. Whitefriars Fire Brigade Station is being equipped as a Superintendent's Station, and Southwark Fire Brigade Station as an Out Station. From the latter there will be two loop circuits comprising 28 call points. The two stations will be connected by Junction circuits, and the operation of a call point will transmit the code of the particular call point to both Stations. The signals will be received audibly on gongs and permanently on a tape which will also be dated and timed. As is generally known, in the Gamewell System a permanent current of 100 mA. is maintained on the call point circuits, the signals from the points being produced by mechanism which interrupts the permanent current a definite number of times corresponding to the number chosen as the code of the point. The circuits are therefore under constant test and the arrangements at the controlling station are such that faults on the system are at once revealed. It is possible for the system to continue working with a disconnection in the line circuit, and a single earth fault will not put it out of action. It is also claimed to be proof against accidental false alarms. The working of the present installation will be watched with interest, as upon its success or otherwise will probably depend the decision of the L.C.C. to adopt a similar system throughout London.

SOUTH MIDLAND DISTRICT.

Locating the Crosses in Split Cable Pairs,

by E. P. Brown (South Midland District).

The following method has been found useful in locating the point at which certain irregular crosses, in split pairs, have been made during jointing operations in twin and multiple twin cables.



The split pairs are connected up and joined to the slide wire as shown in the diagram. For the purpose of rendering the capacities x^1 and y^1 ineffective during the test, the connection between C and D at the near end also A_1 and C_1 at the distant end, are made.

By adjusting the slider a point will be found where silence in the telephone will be obtained, or, as is most usual with this test, minimum sound will be heard in the telephone at some point on the slider.

For a balance

$$\frac{Q}{P} = \frac{\frac{l}{\omega Y}}{\frac{l}{\omega X}} = \frac{y}{x} \text{ and } \frac{Q}{P+Q} = \frac{x}{x+y} \quad \ldots\ldots(1)$$

Where $\omega = 2\pi$ frequency.

x = Capacity in farads between A and B.

y = Capacity in farads between B_1 and D_1.

P = Arm of slide wire.

Q = ,, ,, ,, ,,

Assuming the mutual capacity of the pairs to be equal and uniformly distributed throughout the length L, then $x + y \equiv L$.

Substituting in (1)

$$l = L \cdot \frac{Q}{P+Q}$$

Where L = length in yards of section under test

l = distance in yards to cross.

On lengths up to two miles or so, where the test is most useful, *e.g.*, a section containing a

number of joints, good results have been obtained.

On very short lengths, the test becomes less sensitive owing to the loop resistance of the section under test being connected across the slide wire.

A slide wire consisting of a piece of 36 S.W.G. resistance wire stretched on a graduated board 36" long has been used with success, the source of supply for testing current being a buzzer and repeating coil, but of course, a non-reactive slide wire used with a balanced and screened transformer is preferable.

Retirement of Mr. C. G. Roach, A.M.I.E.E.

The retirement of Mr. C. G. Roach last autumn terminated the official career of one of the most genial and stalwart representatives of the band of engineers who have been intimately associated with the work and progress of the Department from their youth onwards.

Mr. C. G. Roach, A.M.I.E.E.

Mr. Roach entered the service as a Boy Learner at Newton Abbot in November, 1883, and was subsequently at Totnes. In 1886 he was appointed telegraphist at Gloucester and was later transferred to C.T.O.

Mr. Roach joined the Engineering Department as a Sub-Engineer in 1897 and, after experience at Holloway Factory, went to South Wales, where, at Pontypridd and Swansea, he was a pioneer in the active development of rural telephone service and opened up many new exchanges in the Rhondda and Swansea Valleys. On promotion to 1st Class Engineer in 1908, Mr. Roach's energies were transferred to Bolton and subsequently, in 1909, he became Sectional Engineer, Plymouth, taking that Section over from the Royal Engineers.

In addition to the local telephone development in the Plymouth area Mr. Roach was engaged in the completion of the Western Underground Cable to Penzance and was prominent in taking over the Marconi Ship and Shore Wireless Station. Following the acquisition of the Marconi installations, the first Departmental Wireless Station was erected at Bolt Head and later replaced by the more powerful Station at Lands End. A paper descriptive of the latter Station was read by Mr. Roach before the Western Section of the Institution of Electrical Engineers in March, 1914.

During the war period, enemy submarines were very active around the Cornish and Scilly coasts and Mr. Roach had many anxious and difficult times maintaining communication with a depleted staff.

On promotion to Assistant Superintending Engineer in the South Midland District in 1925, Mr. Roach took an active part in the work, consequent upon the very rapid growth of the service, and maintained the keenest interest in the latest engineering developments.

During his stay at Plymouth, Mr. Roach became a bowls enthusiast and his prowess as a bowler with many successes to his credit is widely known. In 1922 he was runner-up in the E.B.A. singles final and in 1923, he played for England in all three International games. In the same year he won the Civil Service National Championship Singles and, with his (then) Superintending Engineer as partner, the Pairs also. The games were played on the green of the South London Bowling Club and in winning four finals on one day Mr. Roach set up a record which he will find it difficult to beat. Mr. Roach is a regular competitor at several of the Bowling Tournaments and has

won the Pairs at Bournemouth, besides being runner-up on several occasions with different partners. During his stay in Devon he played regularly in County games and the Berkshire County Bowling Authorities now make frequent use of his services.

Among his other activities Mr. Roach is an ardent Freemason and a Past Master of the Craft.

It is pleasing to record that Mr. Roach retired in full health and youthful vigour. As a token of the esteem and good wishes of his friends and colleagues Mr. Roach was asked to accept an all-mains wireless set. The opportunity was chosen to present it to him at the first I.P.O.E.E. (South Midland Branch) meeting of the session when a large attendance of the members was assembled to hear the Chairman's lecture—"Maxwell—Heaviside—Einstein." Mr. J. E. Taylor, Superintending Engineer, made the presentation in felicitous terms before commencing his lecture.

H.C.G.

NORTH EASTERN DISTRICT.

Underground Work in Grass Margins.

An interesting experiment was made in the North Eastern District recently, at Coneysthorpe, in the County of Broad Acres, where there are still wide grass margins which escaped enclosure in the days when many tracts of such land were filched from the public.

The country at this point is very exposed, and the decision to establish a rural automatic exchange, with the prospect of securing ultimately some 20 subscribers at a village about 1¼ miles from the exchange site, raised the question of overhead versus underground plant. Consideration of this question resulted in a decision to provide an underground line in an unorthodox manner.

Of the 2,129 yards it was found that 1,706 yards was "easy" grass margin, and when a local farmer was approached and his terms sought for the hire of his Fordson tractor plough, he offered to cut the trench for £2!

Figs. 1 and 2 show the tractor at work, under the supervision of the farmer!

A double cut trench of 18″ average depth was made by the plough, *i.e.*, each section was

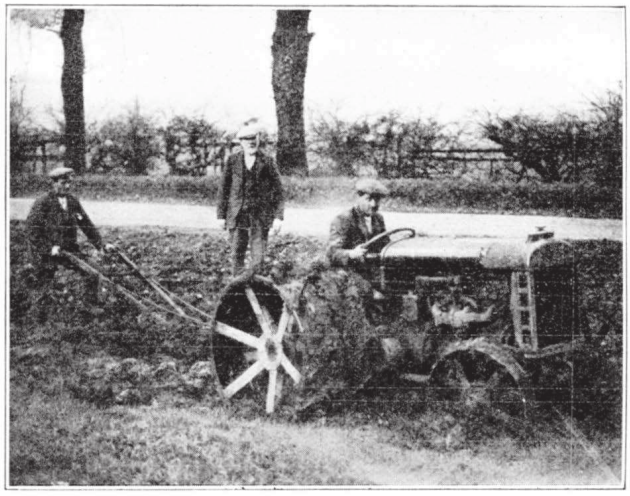


Fig. 1.—Cutting the Trench.

traversed twice. The remaining length of the trench, carriageway entrances and road crossings was cut by manual labour.

It was considered that the local conditions were such that ordinary lead-covered cable, whether laid direct in the ground or placed in wood troughing, would be liable to corrosion; and it was felt also that the life of "protected," *i.e.*, taped, cable would probably be unduly short. The Engineer-in-Chief arranged therefore for the supply of an experimental type of protected cable, the "protection" taking the form of an external coating of "Pernax," the thickness of which is .075″, thus increasing the diameter from the standard (for 25 pr/10) of 0.60″ to 0.75″.

Fig. 2.—Another view.

FIG. 3.—LAYING THE CABLE.

The method of laying the cable in the trench was as follows:—

The cable drum was mounted on one of the Department's freighters, which moved slowly along the road parallel to the track as the cable was paid out. Fig. 3 indicates the method followed.

It was the intention to fill in the trench by means of the tractor plough, but exceptionally wet weather prevented the adoption of that method. Fig. 4 is interesting, as it shows the "Pernax" cable in position and also the character of the grass margin which inspired the experiment, the success of which leaves no room for doubt as to whether it could safely be repeated.

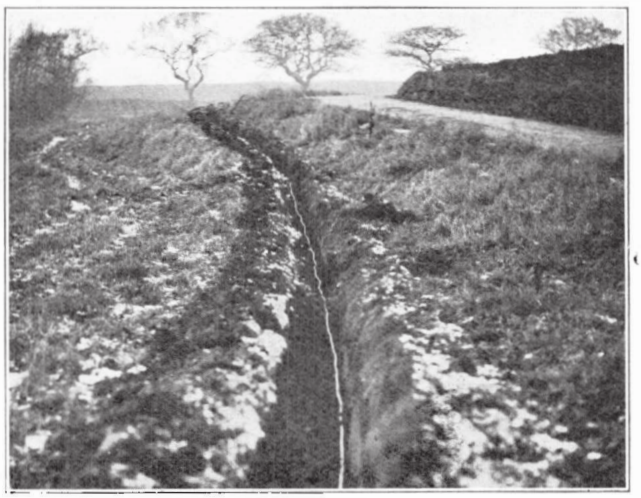


FIG. 4.—THE CABLE IN POSITION.

SCOTLAND WEST DISTRICT.

Work is at present in progress at several points between Ayr and Stranraer and between Stranraer, Port Kail and Knock Bay, in connection with the laying of the underground ducts which are to take the new Ayr-Stranraer, Port Kail, Knock Bay underground cable. This cable will form a link in the new trans-Atlantic telephone service and will also provide improved telephone service between Scotland and Ireland.

The pulling in and jointing of the cable between Glasgow and Ayr is also proceeding. The new cable will contain specially loaded pairs to suit B.B.C. requirements.

A site for a new Repeater Station, conveniently situated with respect to the landing point of the submarine cable which will reach this country from the Atlantic *via* the North of Ireland, has been secured and building plans have been prepared.

The Scotland West District has taken full advantage of the introduction of the new Rural Automatic Exchange equipment; as many as 42 Exchanges of this type have now been opened in this District, with an additional 14 authorised or in progress.

This automatic equipment has proved itself highly satisfactory in meeting the needs of many out-of-the-way places in the Western Highlands of Scotland, as witness the illustration in the last number of the Journal depicting the substantial stone-built structure at Ballachulish at the entrance of the wild and historic Pass of Glencoe. Among other places in the West of Scotland and the Western Highlands of Scotland which have been similarly served might be mentioned Kinlochleven, Spean Bridge, Appin, Onich, Corpach, Strachur, Carradale, and Pirnmill, Machrie and Lochranza in Arran.

Improved telephone trunk service for the Western Highlands is being catered for by the erection of a direct Glasgow-Fort William trunk (Trunk communication to Fort William prior to the provision of this circuit was *via* Oban and Inverness) which was handed over for traffic at the end of January, and trunk communication will shortly reach the outpost of this District on the Mainland when the new Exchange at Mallaig is opened with a trunk circuit Mallaig to Fort William.

In Glasgow itself, two new C.B. No. 1 Manual

Exchanges have been opened. These will afford relief to the existing exchanges of Langside, Giffnock and Western.

At Ayr and Prestwick installation work in connection with new automatic exchanges is in progress. At the former, the equipment will consist of a manual board of 11 positions (ultimate 17 positions) and automatic equipment for 1835 subscribers' lines (ultimate 3860). At Prestwick, which will be a satellite exchange to Ayr, the equipment is for 560 subscribers' lines with an ultimate of 1260.

In both these places the new automatic equipment will replace old magneto exchanges.

Tyneside area could not fail to receive a substantial impetus by the official visit of the Lord Mayor of Newcastle and party to the new Central Automatic Exchange, Newcastle, on the afternoon of Thursday, the 5th February, 1931. The Postmaster-Surveyor, Superintending Engineer, Northern District, and District Manager, with their respective staffs, co-operated to give to a most important assembly of gentlemen drawn from the area an indelible impression of the spirit of service of the Department as evidenced in the transfer to automatic working of the Newcastle Telephone System.

The guests comprised the Lord Mayor of

OFFICIAL VISIT OF CIVIC PARTY TO NEWCASTLE CENTRAL AUTO EXCHANGE.
Photo by Journal and North Star, Newcastle.

NORTHERN DISTRICT.

OFFICIAL VISIT OF CIVIC PARTY AND REPRESENTATIVES OF CHAMBER OF COMMERCE AND PUBLIC UTILITY UNDERTAKINGS TO NEWCASTLE CENTRAL AUTOMATIC EXCHANGE.

The preservation of good relationships between the Post Office and the general public in the

Newcastle-on-Tyne (Alderman David Adams), and Lady Mayoress, the Sheriff (Dr. Leech), members of the City Council, the Mayors of Gateshead, Wallsend, and Jarrow, the Chairman of adjacent Councils, the Chairman of the Postal Sub-Committee of the Chamber of Commerce (Mr. Charles Irwin), Lord Kirkley, Sir Arthur Lambert, Mr. Herbert Shaw (Secretary of the

Chamber of Commerce), Mr. E. S. Byng (Managing Director of Standard Telephones & Cables, Ltd.), and many other prominent gentlemen.

The party assembled in the Dining Room of Telephone House and was accorded a welcome by the Postmaster-Surveyor (Mr. F. Ferguson) who remarked that the transfer which had taken place at midnight on the 31st January, under adverse circumstances in point of weather, had proved to be wholly successful, and had provided a service which was working very smoothly. The District Manager (Mr. J. D. W. Stewart) said that the installation just opened had put the Newcastle Area in the forefront, as regards telephone advancement, not only of this country but of the world. He would, however, like to mark the passing of the old system by an expression of his appreciation of the work of the women of the Department who had operated the manual system for a long period in circumstances which called for qualities of patience and tolerance. The Superintending Engineer (Mr. F. G. C. Baldwin) welcomed the guests on behalf of the Engineering Department and referred to the development of telephone switching devices culminating in the system installed in Newcastle, which represented the product of the best brains available practically throughout the world. He remarked that the Newcastle transfer had raised the percentage of telephone exchange lines worked on an automatic basis in this District from 17.7 to 50, and compared the latter figure to the national figure, which, in November last, stood at 37. He gave a brief description of the improvements effected by automatic apparatus and referred to the fact that the actual transfer of the Central Exchange and its eleven satellites had been completed in eight minutes. He paid a tribute to the work of the Standard Telephones & Cables, Ltd., and drew pride from the fact that the complicated network of underground cabling plant had been designed and installed by the staff of the Northern Engineering District.

The party then divided itself into twelve groups under the direction of an equal number of members of the P.O. Engineering staff as guides and, commencing from several points, the groups simultaneously and without confusion made a tour of the Exchange. Each point from the Power Room to the Auto Manual Switch Room, where Traffic Officers took charge, was explained to the visitors, and from the interest displayed and the questions asked it was evident that they were considerably intrigued by the intricate apparatus, and appreciative of the importance of the function of each part of the installation.

The party again assembled in the Dining Room to have tea, in the course of which Mr. L. Simon, Director of Telegraphs and Telephones, speaking from the Secretary's Office, London, gave a message, amplified by two loud speakers, to the Lord Mayor. Mr. Simon said " It gives me much pleasure to have this opportunity of sending a word of greeting and good wishes to the municipal heads and prominent citizens of Newcastle and the neighbouring towns. Yours is among the earliest of our big industrial areas to change from the manual to the automatic telephone system, which represents the latest stage of technical development in the field of telephony. I may be permitted to express the hope that the new system will commend itself to the subscribers, present and future, and that the telephone will continue to play a part of ever-increasing usefulness in the manifold business and social life of your great community."

The Lord Mayor, in reply, paid a tribute to the efficiency of the Post Office Engineers and expressed his satisfaction at the installation of the automatic system in the " Metropolis of the North." He asked the Director to convey a message from Tyneside to his (the Lord Mayor's) friend, the Postmaster-General, in which the hope was expressed that a reduction of telephone rates would result from the introduction of more efficient and economical apparatus. Mr. Simon replied that he was pleased to hear the expression of appreciation, but could not be expected at that moment to give any opinion regarding the suggested reduction of telephone rates. He would, however, convey the message to the Postmaster-General.

The Lord Mayor then addressed the visitors and expressed appreciation of the efforts of the Department in the dispersal of the operators rendered surplus by the change-over. He congratulated all concerned in the installation and expressed his pleasure at the opportunity afforded that afternoon of viewing the working of the new system.

The Sheriff, following, described the exchange as " a veritable wonder house," and expressed his thanks at being allowed to accompany the Lord Mayor on the visit.

The Chairman of the Postal Sub-Committee of the Chamber of Commerce (Mr. Charles Irwin) alluding to the fact that the Exchange building had been erected on the site of the old Newcastle Gaol, said that the presence of the Sheriff on such an occasion in contrast to the occasions on which Sheriffs had formerly visited the site evidenced the progress of the age. He referred to the facilities provided to Tyneside business men by the Telephone system in being able rapidly to communicate with the merchants of the world, and spoke of the cordiality of the relations between the Chamber of Commerce and the Post Office officials of the District. A proposal by Mr. Irwin of a vote of thanks to the local Post Office Authorities for their hospitality was carried with acclamation.

Mr. Ferguson concluded the proceedings by expressing the thanks of the local officials for the attendance of the visitors.

The Inauguration of the Automatic Telephone System, Newcastle-on-Tyne, January 31st, 1931.

By an Eye-witness.

The last day of January, 1931, was destined to be a memorable one in the history of telephony in the extreme north of England, for it marked the passing of the old manual system which had faithfully served for so long and its replacement by automatic switching methods in Newcastle-upon-Tyne and a large portion of the surrounding territory known as Tyneside. The day dawned bright and clear and gave promise of favourable conditions for the conversion to automatic working of the subscribers' lines comprised in the huge Newcastle and district telephone system which was due to take place at midnight. Later in the morning some concern developed in the minds of the older members of the Post Office Engineering staff who were due to take part in the transfer operation, when snow of that peculiar consistency which always gives cause for apprehension to the telephone engineer, accompanied by boisterous wind, commenced to envelope the town and countryside. By evening a white snow mantle overlay a bog of slush, except in the towns where traffic had obliterated the disguise.

Towards midnight, the storm at its height, a group of participants in the night's telephonic undertaking approached the scene of the principal operations, splashing, slipping, struggling through the churned quagmire, now ankle deep, and the outlook was, at least for one, enlivened by sudden but fortunately painless " full contact " with the semi-fluid mass. " Short-circuit " of the mess, however, was quite impossible, and when the wet and chilly result of the " full earth " was removed from his person, the struggle was resumed.

Observed upon this cold and wintry night with wind-blown flakes of snow, quickly turning to rain, still falling, Telephone House, situated upon the site of the demolished Newcastle Gaol, presented a striking appearance; towering above its now deserted neighbours standing gaunt and grim, with every window of its upper floors ablaze with light, the striking contrast conveyed an impression of some pending event of more than ordinary significance.

Once within the shelter of the portals of the telephone building the striving elements without were very near forgot. The warm and quiet calm which reigned within recalled the atmosphere of some great cathedral standing midst the turmoil of a vast and busy city. The ringing of a distant telephone bell quickly dispelled the impression, however, and revived recollection of the important and delicate task which was pending, and of the fact that this Telephone House in less than an hour was suddenly to become the hub of the communications of the telephone using community of industrial Tyneside. One visualised the underground lead and copper tentacles stretching beneath slushy streets to eleven scattered satellites with lighted windows shining in the blackness, all waiting silently, unostentatiously, for the signal suddenly to summon them to assume their allotted functions.

Within the brilliantly lit apparatus room, to the uninitiated mind, the scene was one of mysterious activity; amongst racks and frames filled with seemingly inanimate devices moved silent apparitions, some white-footed and khaki-clad, vigilant and active, giving final attention to needful apparatus preparatory to its approaching endowment with life.

Without, the city slept beneath its pall of snow, indifferent to, unconscious and, indeed, unmindful of the devotion of some two hundred souls to the requirements of the telephone community.

As the fateful hour of midnight approached numerous figures with cat-like tread and serious mien moved silently to their allotted posts; main frame, protectors, test desk, fuse panel, power board, racks and switches, all were quickly manned. The controlling officer in sombre garb and with solemn step assumed the position from which he would influence the whole of the complex operations. Anxious expectation gave birth to silence, and silence grew; tense became the atmosphere as of some pending consequential ceremonial; quiet reigned supreme; no sound was heard save an occasional word utteried beneath the breath. A recalcitrant switch buzzed somewhere in the recesses of the racks, then paused and stopped, as though shamed by the stillness; but the clock ticked steadily on. The momentous signal that the thirteen old switchboards were clear of traffic, deathknell of the old exchanges, was awaited in almost breathless silence. Still the clock ticked on. Eleven fifty three! Eleven fifty four! Eleven fifty five! Go! At last the controlling officer bestirred. Disconnect! Disconnect Gateshead, disconnect Gosforth Benton, Wallsend. Disconnect Kenton, Low Fell, Jarrow, Felling, Whickham, Central, City. Disconnect! At last the word was given and the signal flashed accordingly to the waiting operatives at a dozen distant points. Silence again ensued, with anxious figures standing by like statues but with thoughts alike of disruptive operations now in progress at those distant places in the snow and winter darkness. Still the clock ticked tranquilly on in indescribable silence, silence almost audible. Into his transmitter now and again with receiver at his ear the controlling officer murmured, whilst with pencil he recorded one by one the executions now in progress. The hand of the clock moved steadily, slowly, persistently on towards the dawn of another day. Tick, tack, click, clack, and the city still slept on. The midnight hour arrived at length. The strokes of midnight boomed from many a steeple far and wide. Midnight chimed from many a turret outside;—but the city still slept on and those within heard not the quivering tones. Presently the controller shifted uneasily in his seat. "Low Fell! Low Fell!" he wailed. "What be the matter Low Fell?" Ah! Low Fell is clear, all clear, all clear at last. The murderous deed is done.

One minute past the midnight hour—six short minutes and the whole of the city's telephones were dead. Not a voice at that moment traversed the copper network of the telephone system of Tyneside. Thirteen old exchanges lay bereft of the lines they had nurtured so well and so long, never again to exercise their former functions. "Not a sound was heard, not a funeral note," but a pang of regret shot momentarily through the hearts of those responsible for the act. Their former cares were slain—slain by their own hand, never more to need the careful attention they had so generously lavished upon them. But banish the thought; with a wave of the arm and a word flashed again over a dozen circuits simultaneously, the signal was given to turn the now severed lines upon the new equipment waiting ready and seemingly expectant to receive them, and in two short minutes it was done. Out of their months of labour, out of their days of travail, out of their hours of test the twelve new exchanges sprang suddenly into life. Wires and circuits, cables and coils, relays and switches, group selectors and finals all were electrified, quickened and summoned to activity. Lamps blinked and winked and glowed; switches buzzed and chattered; a bell tinkled; the birth of the new automatic system was accomplished.

The controller sighed wearily, laid down his receiver, arose from his seat and gravely glanced at the clock. But the city still slept on!

OUTLINE NOTES ON TELEPHONE TRANSMISSION THEORY.

W. T. PALMER, B.Sc. (Hons.), Wh.Ex., A.M.I.E.E.

(SECTIONS 5, 6 AND 7).

SECTION 5.

In addition to the imaginary " infinite " line case, considered in Section 3, three other important practical cases must be considered, viz., the " open " and " short " circuited conditions respectively, for any length of line and the more general case of a line terminated with a given impedance (Z_r).

I. Case of Open Circuit at Distant End of Line.

(See Fig. 7).

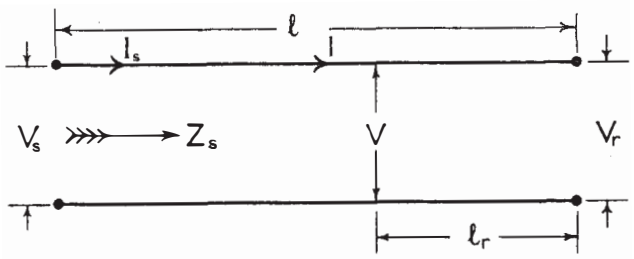


Fig. 7. Open Circuited Line.

(*a*) *Expression for the Impedance (Z_s) Offered at the Sending End.*

The received current will be zero in the open condition and hence by equation (12) of Section 2 :—

$$0 = I_s \cosh \gamma l - \frac{V_s}{Z_0} \sinh \gamma l$$

(where l is the distance to the open circuit).

$$\text{This gives } Z_0 = \frac{V_s}{I_s} \tanh \gamma l$$

$$\text{or } Z_0 = Z_s \tanh \gamma l$$

$$\therefore Z_s = Z_0 \coth \gamma l \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

(*b*) *Expressions for Voltage (V) and Current (I) at any Point Distant (l_r) from the Receiving End of Open Line of Length (l).*

From equation (13) of Section 2 :—

$$V = V_r \cosh \gamma l_r + I_r Z_0 \sinh \gamma l_r$$

But with the open line $I_r = 0$

$$\therefore V = V_r \cosh \gamma l_r \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Now $V_r = V_s \cosh \gamma l - I_s Z_0 \sinh \gamma l$ by equation (11), Section 2, and since $V_s = I_s Z_0 \coth \gamma l$ by equation (1) above, then

$$V_r = V_s \left(\cosh \gamma l - \frac{\sinh^2 \gamma l}{\cosh \gamma l} \right)$$

$$\therefore V_r = \frac{V_s}{\cosh \gamma l} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Hence from equations (2) and (3) :—

$$V = V_s \frac{\cosh \gamma l_r}{\cosh \gamma l} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

For the current, equation (14) of Section 2 gives :—

$$I = I_r \cosh \gamma l_r + \frac{V_r}{Z_0} \sinh \gamma l_r$$

Since $I_r = 0$

$$\therefore I = \frac{V_r}{Z_0} \sinh \gamma l_r \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Now $V_r = \frac{V_s}{\cosh \gamma l}$ by equation (3) above and hence :—

$$I = \frac{V_s}{Z_0} \frac{\sinh \gamma l_r}{\cosh \gamma l} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

II. Case of Short Circuit at Distant End of Line.

(See Fig. 8).

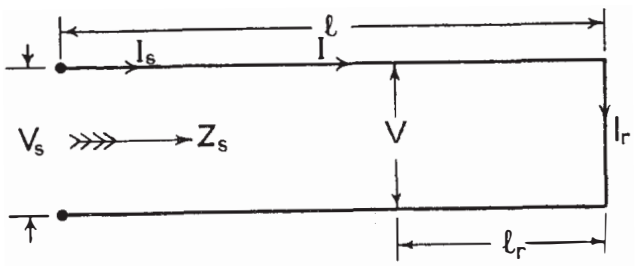


Fig. 8. Short-circuited Line.

(*a*) *Expression for the Impedance* (Z_s) *Offered at the Sending End.*

The received voltage will be zero in the short-circuited condition and hence by equation (13) of Section 2 :—

$0 = V_s \cosh \gamma l - I_s Z_0 \sinh \gamma l$ (where l is the distance to the short circuit).

This gives $Z_s = \frac{V_s}{I_s} \coth \gamma l$

or $Z_0 = Z_s \coth \gamma l$

$\therefore \underline{Z_s = Z_0 \tanh \gamma l}$ .....(7)

(*b*) *Expressions for Voltage* (V) *and Current* (I) *at any Point Distant* (l_r) *from the Receiving End of a Short-circuited Line of Length* (l).

From equation (14) of Section 2 :—

$$I = I_r \cosh \gamma l_r + \frac{V_r}{Z_0} \sinh \gamma l_r$$

But with a short-circuited line $V_r = 0$.

$\therefore I = I_r \cosh \gamma l_r$ .....(8)

Now $I_r = I_s \cosh \gamma l - \frac{V_s}{Z_0} \sinh \gamma l$ and since by equation (7) :—

$$V_s = \frac{I_s Z_0}{\coth \gamma l}$$

$$\therefore I_r = \frac{V_s}{Z_0}\left(\frac{\cosh^2 \gamma l}{\sinh \gamma l} - \sinh \gamma l\right)$$

$$\therefore \underline{I_r = \frac{V_s}{Z_0 \sinh \gamma l}} \text{ .....(9)}$$

From equations (8) and (9)

$$\therefore \underline{I = \frac{V_s \cosh \gamma l_r}{Z_0 \sinh \gamma l}} \text{ .....(10)}$$

For the voltage, equation (13) of Section 2 gives :—

$$V = V_r \cosh \gamma l_r + I_r Z_0 \sinh \gamma l_r$$

Since $V_r = 0$

$$\therefore V = I_r Z_0 \sinh \gamma l_r \text{ .....(11)}$$

Now $I_r = \frac{V_s}{Z_0 \sinh \gamma l}$ by equation (9) above.

$$\therefore \underline{V = V_s \frac{\sinh \gamma l_r}{\sinh \gamma l}} \text{ .....(12)}$$

III. General Case of a Finite Line, Length (l) Closed by any Terminal Impedance

$\underline{Z_r e^{j\phi r}}$. (See Fig. 9.)

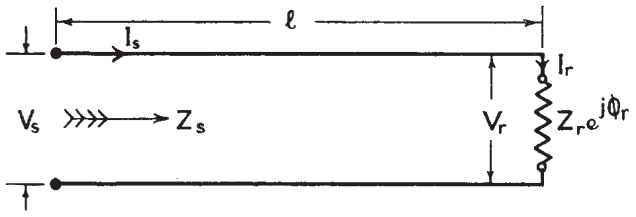


Fig. 9. Line Terminated by Impedance $Z_r e^{j\phi r}$

V_r = p.d. across Z_r.

I_r = current through Z_r.

$$\therefore \frac{V_r}{I_r} = Z_r$$

From equations (11) and (12) of Section 2 :—

$$V_r = V_s \cosh \gamma l - I_s Z_0 \sinh \gamma l$$

$$I_r = I_s \cosh \gamma l - \frac{V_s}{Z_0} \sinh \gamma l$$

Dividing, $\frac{V_r}{I_r} = Z_r$ becomes :—

$$Z_r = \frac{V_s \cosh \gamma l - I_s Z_0 \sinh \gamma l}{I_s \cosh \gamma l - \frac{V_s}{Z_0} \sinh \gamma l}$$

$$\therefore I_s Z_r \cosh \gamma l - V_s \cdot \frac{Z_r}{Z_0} \cdot \sinh \gamma l = V_s \cosh \gamma l - I_s Z_0 \sinh \gamma l$$

Collecting terms :

$$\therefore I_s (Z_r \cosh \gamma l + Z_0 \sinh \gamma l) = V_s \left(\cosh \gamma l + \frac{Z_r}{Z_0} \sinh \gamma l\right)$$

$$\therefore \frac{V_s}{I_s} = \frac{Z_r Z_0 \cosh \gamma l + Z_0^2 \sinh \gamma l}{Z_0 \cosh \gamma l + Z_r \sinh \gamma l} = Z_s$$

$$\text{or } \underline{Z_s = Z_0 \left\{\frac{Z_r \cosh \gamma l + Z_0 \sinh \gamma l}{Z_0 \cosh \gamma l + Z_r \sinh \gamma l}\right\}} \text{ .....(13)}$$

Note 1.—If Z_r has the value Z_0 then equation (13) becomes :

$$\underline{Z_s = Z_0} \text{ .....(14)}$$

which is an important equation, as it shows that *if a uniform line of any finite length be*

terminated by an impedance equal to its characteristic impedance (Z_0) then the **sending end impedance is Z_0,** *and the line therefore behaves as an infinite line (Cp. equation 1, Section 3): i.e., the* impressed wave is propagated smoothly, without reflection at the distant end.

Note 2.—If the receiving impedance is short-circuited so that $Z_r = 0$, then equation (13) becomes :—

$$Z_s = Z_0 \tanh \gamma l \quad \ldots\ldots(15)$$

which is the expression derived in equation (7) for the short-circuited line.

Note 3.—If the receiving impedance is disconnected, so that $Z_r = \infty$, and equation (13) is written in the form :—

$$Z_s = \frac{Z_0 \cosh \gamma l + \frac{Z_0^2}{Z_r} \sinh \gamma l}{\frac{Z_0}{Z_r} \cosh \gamma l + \sinh \gamma l}$$

then putting $Z_r = \infty$ in this equation :—

$$Z_s = Z_0 \coth \gamma l \quad \ldots\ldots(16)$$

which is the expression derived in equation (1) for the open-circuited line.

Note 4.—If the open-circuit or " free " impedance of a given circuit be written Z_f and the short-circuited or " closed " impedance written Z_c then by equations (1) and (7) :—

$$\sqrt{Z_c Z_f} = Z_0 \quad \ldots\ldots(17)$$

and

$$\sqrt{\frac{Z_c}{Z_f}} = \tanh \gamma l \quad \ldots\ldots(18)$$

Equations (17) and (18) have a very important practical application, because the values Z_c and Z_f of a circuit are readily measured by a simple A.C. bridge (See later notes for examples) and thus *from these two measurements both the circuit parameters Z_0 and γ are easily calculated at any desired frequency.* The former of these, Z_0, is useful in determining the best terminating impedance required, whilst the latter, $\gamma = \beta + j\alpha$, will give the attenuation of current and phase-angle change produced at the frequency of test. (Cf. later Section on Line Attenuation Measurements).

SECTION 6.

I. Wave Distortion in Cables.

From equation (18), Section 2, it is clear that as the frequency increases so does the attenuation constant β, so that for the higher harmonics of a given impressed wave-form the attenuation is greater, on a given length of cable, than for the fundamental. Also, from equation (19), Section 2, the wave-length constant is different for each harmonic of the complex wave, *i.e.*, the velocities of propagation of the harmonics are different. Thus while in an actual pair of conductors about 30 miles long the vowel sound of " O " gives an oscillographic record approximately that shown in Fig. **10** (*a*) at the *beginning* of the line, at the *end* of the line the record is more like that shown in Fig. **10** (*b*). This shape is

Fig. 10a. Sent Signal.

Fig. 10b. Received Signal.

smoother—with much less third and higher harmonics, having slightly different phase relationships—and generally diminished in amplitude. So all sounds become smoothed or " distorted " and do not re-appear as they are sent (because of the distinctive higher harmonics which are lost) unless the distortion is stopped or minimized. If all frequencies could be transmitted with equal attenuation and their velocities made the same, the problem of " amplitude distortion " (caused by unequal attenuation of harmonics) and " phase distortion " (caused by unequal wave-lengths of harmonics) would be

solved. In practice the problem can be partly solved in the case of the transmitting line by adding inductance to the natural inductance of the cable circuits. The reason for this is discussed briefly as follows:—

Distortionless Condition.—Heaviside wrote equations (18) and (19) of Section 2, in the form—

$$2\beta^2 = \sqrt{(GR+\omega^2LC)^2+\omega^2(LG-CR)^2} + (GR-\omega^2LC)$$

and $$2\alpha^2 = \sqrt{(GR+\omega^2LC)^2+\omega^2(LG-CR)^2} - (GR-\omega^2LC)$$

respectively.

From these expressions it is clear that:—

if $\frac{R}{L} = \frac{G}{C}$ .....(1)

then $\beta = \sqrt{RG}$ .....(2)

and $v = \omega\sqrt{LC}$ .....(3)

so that that the attenuation (β) is *independent of frequency* and the propagated wave velocity, (v) of all frequencies is *independent of frequency* (since $v = \frac{\omega}{\alpha}$ and $\alpha = \omega\sqrt{LC}$ by equation (3)) and is equal to $\frac{1}{\sqrt{LC}}$. Therefore no distortion of any harmonic of a complex wave takes place and the wave maintains its shape in such a line—which is known as a "*distortionless*" *line*. Again, from consideration of equation (1):—

$$Z_0 = \sqrt{\frac{R}{G}} \text{ or } \sqrt{\frac{L}{C}} \quad \text{.....(4)}$$

which shows that Z_0 is also independent of frequency and hence all waves encounter the same impedance when transmitted over a line whose electrical constants bear the relation CR = LG.

Further, it is easy to prove that $\beta = \sqrt{RG}$ (equation (1) above) is the *minimum value* of β. See Example 2 at end of Section.

Now in actual circuits the *natural* inductance of the conductor is so small that $\frac{R}{L}$ is much greater than $\frac{G}{C}$, *e.g.*, 1 mile of Standard Cable having

R = 88 ohms per mile loop
L = 0.001 henry per mile loop
G = 1×10^{-6} mho. per mile loop
C = 0.05×10^{-6} farad per mile loop

gives the ratios:—

$$\left.\begin{aligned}\frac{R}{L} &= 88{,}000\\ \frac{G}{C} &= 20\end{aligned}\right\}$$

which represents the order of inequality for ordinary air-space paper-core cables.

Again, 1 mile of aerial line having

R = 2.2 ohms per mile
L = 0.00332 henry per mile
G = 1×10^{-6} mho. per mile
C = 0.01×10^{-6} farad per mile

gives the ratios:—

$$\left.\begin{aligned}\frac{R}{L} &= 660\\ \frac{G}{C} &= 100\end{aligned}\right\}$$

which represents an inequality, but much less than that existing in paper-core cables.

As it is desirable to make $\frac{R}{L} = \text{or} \rightarrow \frac{G}{C}$, Heaviside originally suggested (in 1887) that increased inductance would be beneficial for a loop circuit used for speech transmission. Another method of making $\frac{R}{L} \rightarrow \frac{G}{C}$ is to increase the leakance factor (G) and this has been tried, but the greater attenuation which results is undesirable in long circuits.

Heaviside's suggestion, however, of increasing, in some manner, the inductance has the advantage of *decreasing* the attenuation when the added inductance is correctly introduced. (See Section 7). The following simple example 1 will illustrate this advantage of increased inductance apart from the question of the practical methods adopted for artificially increasing L:—

Example 1.—Consider a cable having the electrical constants per mile loop, R = 88 ohms, L = 1 millihenry, C = 0.05 μF. Then neglecting G and taking ω = 5000 radians per second

(corresponding to mean speech frequency) the attenuation (β) per mile loop is calculated from:

$$2\beta^2 = \omega C\{\sqrt{R^2 + \omega^2L^2} - \omega L\}$$

—which is equation (18) of Section 2 with G put equal to zero. This gives

$$\beta \fallingdotseq 0.100 \text{ neper per mile loop} \quad \ldots\ldots\ldots\ldots(1)$$

[For definition of neper see later Section on Transmission Units.]

If now L is artificially increased to 100 millihenries per mile loop *in such a way as to be considered uniformly distributed* throughout the cable length then from:—

$$2\beta^2 = \omega C\{\sqrt{R^2 + \omega^2L^2} - \omega L\}$$

$$\beta = 0.033 \text{ neper per mile loop} \quad \ldots\ldots\ldots(2)$$

$$\fallingdotseq \text{one-third the value given in (1).}$$

In other words the transmission efficiency, as measured by volume of received sound at one definite frequency, is much greater in the case of L = 100 mH., than in the ordinary cable with L = 1 mH. Further, the value of $\frac{R}{L}$ is decreased, by the extra inductance, from 88,000 to 880—a figure much nearer the value for $\frac{G}{C}$, which is of the order of 20 for ordinary paper-core cables.

Example 2.—To prove that $\sqrt{RG}$ is the *minimum* value of β. By differentiating, with regard to L, the expression:—

$$2\beta^2 = \sqrt{(R^2 + \omega^2L^2)(G^2 + \omega^2C^2)} + GR - \omega^2LC \quad \ldots\ldots(1)$$

the result is:—

$$4\beta \cdot \frac{d\beta}{dL} = \frac{\omega^2L\sqrt{G^2 + \omega^2C^2}}{\sqrt{R^2 + \omega^2L^2}} - \omega^2C$$

For β to be a minimum put $\frac{d\beta}{dL} = 0$ and this gives the condition:—

$$LG = CR$$

By substituting this condition in (1) the minimum value of β is found to be—

$$\beta = \sqrt{RG}.$$

Example 3.—What loading will be necessary to produce distortionless transmission in a line having the following loop-mile constants:—R = 6.3 ohms, L = 0.06 henry, G = 0.15 micromho, C = 0.054 microfarad? Find the attenuation constant before and after loading. (*C. & G., 1930*). [f = 800 p.p.s.]

Example 4.—Show that the current at a distance x miles from the sending end of a telephone line, of length l miles, which is open-circuited at the receiving end, is given by—

$$I = \frac{V_s}{Z_0} \cdot \frac{\sinh \gamma(l - x)}{\cosh \gamma l}$$

where V_s is the voltage at the sending end, γ the propagation constant, and Z_0 the characteristic impedance.

If V_s = 10 volts, $\gamma = 0.15 + j\,0.786$, $Z_0 = 725 \angle 10^\circ$, l = 15 miles, find the current at distances (x) of 5 and 10 miles from the sending end. (*B.Sc. Final, 1929*).

[See equation (6) of Section 5.]

Section 7.

Loaded Cables.

The inductance added to a cable primarily to produce distortionless transmission, by forcing all components of the complex speech wave to attenuate more nearly at the same rate and travel more nearly with the same velocity, is generally introduced in practice by one of the two following methods:—

(I.) By means of inductance coils inserted in series at regular intervals along the line. Such inductance coils limit the wave-length which can be transmitted (*i.e.*, there is a certain maximum frequency above which transmission becomes very inefficient and eventually impossible) in exactly the same way as *lumped loads* upon a stretched, uniform, vibrating string limit the wave-length which it will transmit. (See References at end of Section). It is this analogy which has caused the series inductance coils to be regarded as electrically lumped loads and they are generally called "*loading*" *coils*.

(II.) By the provision of one or more layers of iron (or iron alloy) wire wound upon each conductor of the loop and known as *continuous-loading, uniform-loading* or *Krarup-loading*.

I. Coil-loaded Lines.—Professor Pupin (1890) first arranged to have inductance coils specially prepared and placed at equal intervals along the line. Thus the method is variously known as the Pupin-system, Series-method, Coil-loading method, or Lumped-loading method. In this system the *correct spacing* of the loading coils to produce the equivalent effect of a uniform loading, is a matter for a rigid mathematical investigation which at this stage is not required. [See later Section of Notes on Equivalent Networks and Campbell's Formula for the propagation constant of a coil-loaded line.] It is sufficiently instructive here to consider the mechanical analogy of a stretched string loaded by small weights at equal intervals along its length and which can be proved to vibrate practically as though *uniformly loaded* if there be *not less than* π *loads per the wave-length which it is desired to transmit.* From analogy *there must be at least* π series inductance coils per wave-length, λ, of an electrical wave if a circuit is to behave as a uniformly loaded circuit. Thus π *coils per wave-length* is a limiting condition and the circuit will not transmit higher frequencies efficiently. Now to obtain sufficiently clear speech for practical purposes it is sufficient if the harmonics up to a frequency (f_m) of the order of f_m = 2000 p.p.s. only are transmitted, *i.e.*, in a coil-loaded cable there must be *at least* π coils per wave-length at a frequency of f_m = 2000 p.p.s. *If this upper frequency of the transmitted band of frequencies were the only consideration* the following rule (once used in the Post Office as a coil-spacing rule) is of interest:

Let λ = wave-length at f p.p.s.

d = spacing of coils in miles

$\therefore \quad \lambda = \pi d$ (Cf. pp. III. of Section 3).

But $$\lambda = \frac{2\pi}{\alpha} = \frac{1}{f_m \sqrt{CL}}$$

$$\therefore \pi d = \frac{1}{f_m \sqrt{CL}}$$

Hence if f_m = 2000 and L_1 = inductance of each loading coil, then since $L_1 = \frac{L}{d}$

$$\therefore \quad CL_1 d \fallingdotseq 25$$

If f is to be > 2000 then the constant 25 in this equation must be decreased.

It will be seen later that consideration of phase distortion, echo effects, cross-talk requirements, permissible repeater gains, etc., have modified the above simple relationship in practice and it can merely be expressed as $CL_1 d < 25$.

Actual Spacing values used for *U.G. circuits* are from $1\frac{1}{8}$ miles to $2\frac{1}{2}$ miles approximately, [In the case of special circuits such as music or carrier circuits 1,000 yards spacing and light loading is employed.] for *submarine cables* from 1 to 2 nautical miles, and *aerial lines* (if loaded at all) from 8 to 12 miles. (See (4) below). The aerial lines do not require such heavy loading because of their higher natural inductance and lower capacity. (Cf. example in Section 6).

The actual loading coils are formed of rings of iron (or magnetic alloy) wound in sections with insulated wire so that one half the winding is in each limb of the circuit (with the magnetic effects additive) and the *balance* of electrical constants (R, L, G and C) is thus disturbed as little as possible. (Fig. **11** refers). The following is a summary of the general requirements for these coils:—

(1) *Low conductor resistance*—of the order of 5 to 15 ohms.

(2) *High insulation resistance*—of the order of 10^4 to 10^5 megohms between windings with 100 volts D.C.

(3) *Low capacity between windings*—of the order of 3×10^{-3} microfarad.

(4) *Magnetic stability* with time and current, *i.e.*, the value of L must not change.

As a rule the coils are designed so that $\frac{R}{L}$ of a coil is as small as possible—from 25 to 50. So that taking $\frac{R}{L}$ = 50 and R = 6.5 to 12.5 ohms the corresponding values of L are L = 130 to 250 milli-henries. For smaller values of L with a ratio of $\frac{R}{L}$ = 70 and R = 1.12 ohms the value of L is 16 milli-henries.

(5) Non-interference between coils of neighbouring circuits—generally obtained by efficient closed magnetic circuits and by screening.

(6) Economy of space.

(7) Reasonable cost.

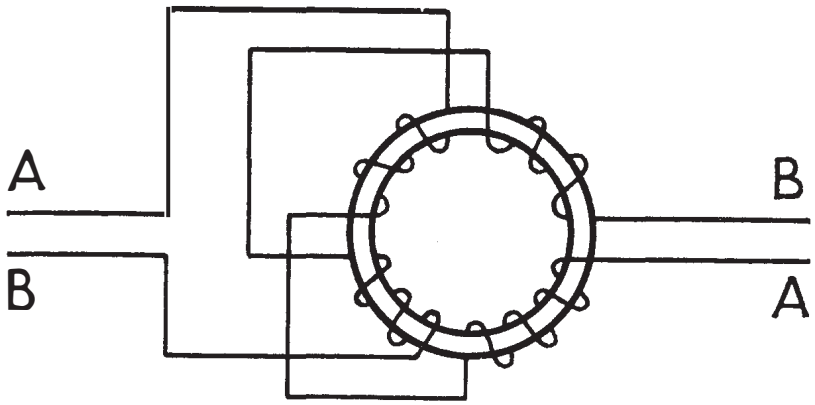


FIG. 11.—SIDE CIRCUIT LOADING COIL.

Phantom Circuits and Phantom Loading.—The conductors, in Fig. **12**, of a four-wire unit in a star-quad cable or multiple-twin cable can be arranged during manufacture so that there is little or no mutual inductance between the pairs of the circuit and thus no interference (cross-talk) due to this factor. It is more difficult, however, to arrange the balance of the

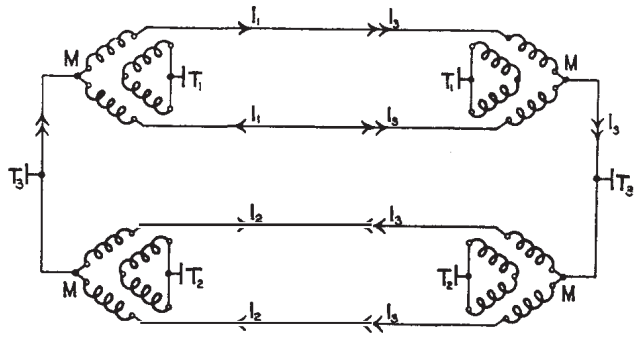


Fig.12.

various capacities between wires, so that no interference results, and this balance has to be obtained as far as possible during installation of the cable lengths. (See later Section of notes).

A third circuit can be obtained as in Fig. **12**, using the two wires of No. 1 circuit in parallel as one limb and both wires of No. 2 circuit as the other limb. (Difficulty is in this case experienced in arranging the wire *and* earth capacities, so that little or no cross-talk takes place from the side circuits to the third circuit and this feature is dealt with in later notes). This third circuit is called the "*phantom*" circuit and its constituent pairs are called the "*side*" circuits. The tapping points, M, must of course be in the electrical and magnetic centre of the side circuit transformer windings so that currents from No. 3 circuit split in opposite but equal amounts and do not disturb telephones T_1 and T_2 by "overhearing" at these terminations.

The phantom circuit is loaded as indicated in Fig. **13**, and where the phantom coil has in effect both wires of each side circuit wound on

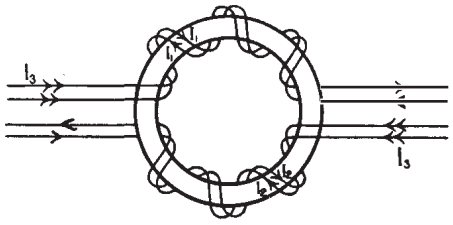


Fig.13.-Principle of Phantom Coil Winding.

the magnetic core in such a way that only I_3 produces any magnetic flux, but I_1 and I_2 have their respective magnetic effects neutralized.

(Section 7 to be continued.)

Further References:—

Prof. Pupin—Trans. Am. I.E.E., March 22nd, 1899, and 19th May, 1900.

Prof. Routh—"Advanced Rigid Dynamics," p. 260.

Lord Rayleigh—"Theory of Sound," Vol. 1, p. 233.

Dr. G. A. Campbell—Phil. Mag., 1903, Vol. 5, p. 313.

Dr. F. Luschen and K. Küpfmüller—Journal I.P.O.E.E., Vol. 20, Part 3, p. 207.

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS.

LONDON CENTRE NOTES.

The third meeting of the Session, presided over by Mr. Gomersall, was held on Tuesday, December 9th, 1930, when Mr. A. O. Gibbon, M.I.E.E., read a paper entitled " The Electrical Control of Time Services in the British Post Office."

There was a good attendance and the discussion was opened by the Astronomer Royal, Sir Frank Dyson. Amongst others who took part in the discussion were Mr. H. R. Kempe, a former Chief Electrician of the Post Office, Col. Edgecombe, past-President of the Institution of Electrical Engineers, Mr. F. Hope-Jones and Col. Angwin.

The paper and discussion brought out the varied applications of automatic timing devices in the Post Office.

The fourth meeting, presided over by Mr. Gomersall, was held on Tuesday, January 13th, 1931, when Mr. F. R. Perris, A.C.G.I., B.Sc. (Hons.), D.I.C., A.M.I.E.E., read a paper entitled " Secondary Cells."

There was a good discussion, ranging from academic theories to practical difficulties. Mr. Perris ably replied to the many points raised.

The fifth meeting, presided over by Mr. Gomersall, was held on Tuesday, February 10th, 1931, when Mr. W. R. Tyson, B.Sc. (Eng.), A.M.I.E.E., read a paper entitled " The Equipping of Automatic Exchanges."

The paper provoked an interesting and lively discussion, several manufacturers being keenly interested.

Informal Meetings.

The third informal meeting, presided over by Mr. Gomersall, was held at Denman Street on Tuesday, January 27th, when Mr. H. W. Fulcher, A.M.I.E.E., read a paper entitled " Ventilation of Telephone Exchanges." The paper was illustrated by lantern slides and a collection of testing instruments, air filters, etc., was available for inspection. The paper aroused an interesting and instructive discussion which brought out the fact that much time and thought has been given to ventilation. Mr. Fulcher ably replied to the many points raised and afterwards explained and demonstrated the uses of the various exhibits.

The fourth informal meeting, presided over by Mr. P. T. Wood, was held at Denman Street, on Tuesday, February 24th, 1931, when Mr. E. H. Slattery read a paper entitled " Public Wayleaves : a few Observations."

The paper dealt exhaustively with the question and a good discussion, to which Mr. Slattery replied, contributed to the knowledge of many of the members.

In each case there was a stimulating discussion, which further emphasized the very great value of these informal discussions to the staff and to the Department. The large attendance shows how greatly these discussions are appreciated, but there is still room for those who wish to gain knowledge of matters with which they are dealing or may have to deal at some future time.

T.H.

NORTH WESTERN CENTRE.

A meeting of the Centre was held on the 15th December, 1930, when a paper entitled " Unit Costs ; Their use in the control of Expenditure and as an aid to the supervision of Works " was read by Mr. S. Upton, M.I.E.E., before a good attendance. At the outset, Mr. Upton drew special attention to the title of the paper and emphasised that he proposed to discuss U.M.C. and U.C.C. as a machine for use in the control of expenditure and an aid to supervision, *i.e.*, starting from the completed monthly statistics. Beyond a brief description of the work involved in compiling the statistics therefor, the paper dealt with their practical use by Sectional Engineers and their staff and included actual examples of good and bad methods.

During the general discussion which followed, graceful reference was made by Mr. Finlayson (opening the discussion) and other speakers to Mr. Upton's approaching retirement and to the part he had taken in the I.P.O.E.E. meetings by contributing papers and helping in the discussions. The Chairman (Mr. J. M. Shackleton, M.I.E.E.) echoing these sentiments said that Mr. Upton had only to say the word and they

would gladly arrange for a special meeting so that they might have the pleasure of listening to yet another paper from him. One thing he would miss very much indeed was Mr. Upton's contributions to discussions—he had regarded him as a sort of reserve and standby—he could always be relied upon to step into the breach and revive a flagging discussion.

Other papers read during the Session were—one from Mr. A. Diggle on the "Rochdale Automatic Exchange—Some interesting features," and one on "Rural Automatic Exchanges" from Mr. T. F. Levens.

An exhibition of official films given in November last with an interesting running commentary by Mr. W. H. Albry (Engineer-in-Chief's Office) was much appreciated by a large audience, which included the District Manager (Mr. J. K. Murray) and many of his staff and a number of the Department's workmen. The exhibition was repeated at Bolton, an outlying centre in the District.

SOUTH LANCASHIRE CENTRE.

The third meeting of the Institution was held on December 15th, when the following departmental cinematograph films were exhibited:—

"Jointing Cables."
"Pole Hole Excavation."
"Pole Shifting."

Mr. Albry, of the Engineer-in-Chief's Office, provided an instructive running commentary during the display. The films evoked great interest as was shown by the questions subsequently raised, to which Mr. Albry ably replied.

At the fourth meeting held on January 12th, four short papers were read.

"Secondary Cells," Mr. W. H. Cross.
"Rural Auto Exchanges," Mr. R. C. Davies.
"Teleprinters," Mr. H. J. Moores.
"The Decibel," Mr. C. E. Morgan.

Although the time available was scarcely sufficient for all the points of interest to be dealt with, good discussions followed. The paper on the application of automatic switching methods to the provision of satisfactory service in rural areas was particularly interesting.

The fifth meeting held on January 27th was the occasion of a joint meeting with the North Western Centre of the Institution of Electrical Engineers and the Manchester Association of Engineers.

The subject of the meeting was a lecture by Mr. S. G. Brown, F.R.S., on "Loud Speakers, Gramophone Pickups and Recording Apparatus." Mr. Brown was unable to be present and the lecture was delivered by Major C. A. Russell Stower. One of the main points of the lecture was the author's opinion that the horn type of loud speaker gives the most satisfactory results, and that it is only a matter of time before this type once again comes into general use. Another view put forward was that the moving coil type of pickup, of which an experimental model was described, is well worth developing.

The lecture was illustrated by lantern slides, and various types of loud speaker and pickup were used to demonstrate the salient points. A carbon microphone pickup was shown to be capable of giving an output sufficient to operate a loud speaker without the use of an amplifier. A demonstration of home recording for the gramophone supplied another element of novelty. Major Russell Stower spoke his concluding remarks into the microphone and the record thus obtained was reproduced before the audience. The meeting terminated with a hearty vote of thanks to Mr. Brown and Major Russell Stower.

Representative gatherings of the staff have been held on two occasions to congratulate two members of the staff, who have earned promotions involving their removal to other parts of the country. The first of these gatherings was held on the 1st January, when Mr. E. R. Davies, Higher Clerical Officer, was presented with a radio set and loud speaker by the staff to mark the occasion of his promotion to the rank of Staff Officer at Cardiff.

On the 2nd February Mr. C. E. Morgan, Assistant Engineer, and late Secretary of the Local Centre of the I.P.O.E.E., who has been promoted to Executive Engineer at York, was the recipient of a pedestal lamp, as a token of the esteem in which he was held by his colleagues.

It is with feelings of deepst regret that we have to record the passing of Mr. W. R. Booth, Inspector, whose death occurred on the 14th January after an illness lasting several months. The funeral ceremony was attended by members of all grades. He leaves behind impressions of

the greatest sincerity and earnestness and of the kindest consideration shown to all with whom he came into contact.

SCOTLAND WEST CENTRE.

The second meeting of the Session was held in the Royal Technical College, Glasgow, on 3rd November. The lecturer was Mr. H. G. S. Peck, B.Sc. (Hons.), M.I.E.E., and the subject "The Director System." There was a good attendance of members and visitors from the Commercial Staffs.

The lecturer approached the subject by first describing a Strowger selector or two-motion switch, indicated the various ways in which selection may be made, and concluded with the trunking chart of the Farme Street Building, which will accommodate four of London's 10,000 line exchanges with directors and other apparatus which will be used in common by them. The limitations of the non-director system when used in multi-office areas, and the application of the director system to the simultaneous operation of automatic and manual exchanges in an area were fully dealt with. A considerable part of the lecture was devoted to an exposition of the adaptability of the director systems to meet the trunking requirements of an area having regard to the number and holding time of calls, the geographical position of the exchanges, the cable routes connecting them, to the increased traffic efficiency of large groups of circuits and the use of Tandem exchanges. The lecturer was at particular pains to explain, with the aid of the blackboard, the method by which the three digits dialled as the initial letters of the exchange name are translated by the director into any required "Code" of from one to three trains of impulses. The lecture was fully illustrated by means of lantern slides.

A well-sustained discussion, or rather series of questions, taken part in by members and visitors, indicated that interest in the lecture had been maintained throughout.

NORTH WALES CENTRE.

The third meeting of the Session was held on 1st December, 1930, when the Chairman, Mr. R. A. Weaver, presided over an audience of almost 200, including 50 workmen and 25 visitors from the higher schools of Shrewsbury, and saw an exhibition of technical films illustrating Bar and Spoon and Auger excavation, L.C. cable jointing, pole lifting and shifting, and the working of an automatic telephone exchange. Mr. Albry (Engineer-in-Chief's Office) was present and lectured on the films as they were exhibited, and the volleys of questions which he had to meet at the end of each reel was sufficient evidence of the keen interest with which the display was followed.

The fourth meeting was held on 15th January, 1931, when Captain N. F. Cave-Brown-Cave, B.Sc., M.I.E.E., read a paper entitled "Some Non-metallic Materials and their Characteristics." The lecture covered Oils, Paints, Varnishes, Cellulose Lacquers and Enamels, Insulating and covering materials, Overhead Line Insulators, Ducts, Cement, Concrete and Timber, and a fine collection of samples of fibres, chemicals, paint and enamel work, etc., etc., was on view. A formidable list of questions was then addressed to the lecturer and in reply to the desire expressed by many speakers that the subject should be completely covered by a further paper on "Metallic Materials used in the Department" Captain Cave-Browne-Cave eventually gave a promise that this would be done next Session.

At the fifth meeting held on 11th February, 1931, Mr. G. H. Carrier read a paper entitled "Some Notes on Electrons," of which the following were the main headings:—

Conductivity of gases.
Electric Radiation and Leakage.
Ionisation of Gases.
Cathode Rays.
Transference of Electricity through solids.
Atomic Structure.
Zeeman effect.
Photo Electric Effect.
Electronic emission by Heat.

The paper was well illustrated by slides and a number of demonstrations were given very effectively. The delivery of the paper and the demonstrations occupied so much time that little was left for discussion, but appreciation of the lecture and the very great trouble which had been gone to in covering so wide a subject, was expressed by the Chairman and several other speakers.

SCOTLAND WEST CENTRE.

At our December meeting the following Departmental films were shown:—

(1) Jointing L.C. Cable—Wire Twisting.

(2) Pole Excavation

(*a*) Bar and Spoon.

(*b*) Iwan Auger.

(3) Pole shifting, Pole lifting jacks.

(*a*) Lifting pole out of ground and placing in new pole hole.

(*b*) Pole Lifting Jacks and Trench method.

Mr. W. H. Albry, of the Engineer-in-Chief's Office, explained the operations shown on the screen as the exhibition progressed and on completion of each spool there was an interval for discussion, which was fully taken advantage of by the members and by the large turn-out of workmen present.

The February meeting was of an informal character and the subjects under discussion were

High Maintenance Costs.
Internal, Underground and Overhead.

The leaders in the discussion were Messrs. Jeary, Bagley and MacIntyre, and the general discussion was well maintained.

A further series of Departmental films was shown at the March meeting—

(1) Assembling and adjusting a Dial, Auto. No. 10.

(2) Wiring and forming a Switchboard Jack.

(3) Hello Europe.

The Chairman directed attention to several points of particular interest shown on the films and the exhibition was generally appreciated.

THE INSTITUTION OF P.O. ELECTRICAL ENGINEERS.

Officers of Colonial and Foreign Telegraph Administrations who are engaged in Electrical Engineering Works may be admitted as Colonial and Foreign Corresponding Members respectively, after application.

Subscription payable annually in advance on 1st April in each year:

Colonial Members	... ...	£1 0 0
Foreign ,,	... ...	£1 10 0

These sums include Annual Subscription to the Journal of P.O. Electrical Engineers and the supply of all Professional Papers issued during the period covered by subscription.

Forms of application for Colonial and Foreign Membership can be obtained on application to

The Secretary,
Institution of P.O.E. Engineers,
G.P.O. (Alder House), E.C.1,

or the undermentioned gentlemen who have kindly agreed to act as representatives of the Institution in their respective countries:—

R. Badenach, Esq., B.Sc. (Melb.),
Chief Engineer's Office,
Postmaster-General's Department,
Treasury Gardens,
Melbourne, C.2,
Australia.

H. C. Brent, Esq.,
District Telegraph Engineer's Office,
Wellington, N.Z.

N. N. Banerjee, Esq., A.M.I.E.E. (Ind.),
Divisional Engineer, Telegraphs,
Calcutta West Division,
8, Wellesley Place,
Calcutta,
India.

A. T. Kingston, Esq., M.B.E., A.M.I.E.E.,
Office of the Chief Engineer,
Telegraphs & Telephones,
C.T.O.,
Colombo,
Ceylon.

A. J. Kellaway, Esq.,
Department of Posts and Telegraphs,
P.O. Box 366,
Pietermaritzburg,
South Africa.

E. L. Jephcott, Esq., A.M.I.R.E.,
Chief Engineer's Department,
G.P.O. Box 391,
Salisbury,
South Rhodesia.

BOOK REVIEWS.

" Telephone Theory and Practice: Theory and Elements." By Kempster B. Miller. London: McGraw-Hill Publishing Co. Pp. xiv. + 486. 25s. net.

One of the first text-books on the subject of Telephony was "American Telephone Practice," first published in 1900. It was greeted with lively enthusiasm by telephone engineers and older readers of this Journal will doubtless remember its debut. Since 1904, when the second edition was published, the author, Mr. Kempster B. Miller, has been unable to find the time to bring his book up to date. When the opportunity *did* present itself, Mr. Miller found that his early work needed totally re-writing and he decided to leave it as a historical record of the telephone practice of the preceding generation and to provide a new work dealing with present-day practice.

So complex has the subject become that Mr. Miller has found it necessary to divide his subject into three sections, to each of which a separate volume is devoted; the volume which is the subject of this review is the first in the series and is to be followed by two further volumes, " The Telephone Exchange " and " Lines and Transmission," which are in course of preparation.

In the first volume, the author sets out to gather together all the scientific data and facts which form the foundation of present-day telephone practice. In the first part, he gives a brief survey of the development of speech and language and shows how Man has endeavoured to obtain a range of communication beyond the limits of his voice. The last chapter of this part is devoted to a discussion of the various components which go to make up a telephone system.

The first three chapters in Part II. are devoted to a study of sound in its relation to the human voice and ear. Telephone engineers have come to realise the necessity of a knowledge of the precise manner in which the ear, in conjunction with the brain, interprets the sound waves reaching it, and these chapters owe much of their lucidity to the researches of Dr. Harvey Fletcher and his colleagues in the Bell Telephone Laboratories. The upper and lower limits of audibility and the threshold of hearing and feeling are discussed at considerable length and some attempt is made to account for them in the light of Fletcher's modification to Gray's " maximum amplitude theory." The author quotes several interesting experiments which show that the mechanism of the ear supplies, subjectively, components which, although present in the original sound waves, are not present in the sound waves reaching the ear from the diaphragm of a telephone receiver. The author quotes from Fletcher: " Experimental tests show the rather unexpected result that the elimination of all the harmonic frequencies above 2,000 cycles affects the musical quality of a bass, baritone or a contralto voice to a greater extent than the quality of a high soprano voice." A discussion on the masking effect of tones and the binaural property of the ear, employed in sound ranging, concludes the chapter.

Various kinds of sound are discussed in the following chapter and a description of the organs of speech and the effect of the resonant chambers formed by the mouth and throat is given.

Chapter 8 is devoted to the theory of alternating currents, with special reference to voice currents. A brief description of the principle of line loading, and of low pass, high pass and band pass filters is given.

The next chapter contains a description of the theory of the vacuum tube and describes the principles of amplification, rectification, oscillation, modulation and demodulation.

The last chapter of Part II. provides a survey of the various magnetic materials which are used in the construction of telephone apparatus and considerable space is given to a description of the permalloys and perminvars, two groups of alloys which have been recently discovered.

Part III. contains descriptions of the various elements of apparatus, such as wires for equipment use, coils and electro-magnets, resistors, condensers, flexible cords, and the various contact metals available and the methods in which joints are made.

Mr. Miller is to be congratulated on the very lucid descriptions he has given and the clarity of the illustrations. In gathering together all the

scientific data which are fundamental to a study of telephony, he has rendered a service not only to students of the subject but to the engineer. The book is practically non-mathematical and is extremely interesting to read.

W.S.P.

Binders for A.T.M. Coy's Engineering Bulletins.

We have received from the Automatic Telephone Manufacturing Co., Ltd., bound sets of Engineering Bulletins descriptive of A.T.M. Strowger Automatic equipment and engineering practice. The bulletins are assembled in handsome binding covers in which additional bulletins can be inserted and kept for handy reference.

J.McK.

" The Practical Electricians' Pocket Book, 1931."

The thirty-third edition of this pocket electrical encyclopædia has just been published. Two new chapters have been added to the book. Both of them, " Commutator Troubles and Their Cure " and " Electro-Plating " have been compiled by contributors well known to readers of past editions—C. Sylvester, A.M.I.E.E., and S. Wernick, B.Sc. (London), Hons. Chem. No less than six sections have been so thoroughly revised that they may be said to be new. The Central Station data in which comprehensive supply details for every town of importance in the United Kingdom are given, has been most thoroughly overhauled and the information contained therein is the latest available.

There are sixty-seven chapters containing a thousand-and-one facts, but each fact can be ascertained at a glance by means of a comprehensive detailed subject index arranged in alphabetical form, which alone occupies some twenty pages.

Containing some 600 pages in all, the Practical Electricians' Pocket Book is wonderful value for 2/10, at which price it can be obtained from the publishers, post free.

" Let's Help." Sir Charles Bright, F.R.S.E., M.Inst.C.E., the well-known expert on submarine cables and author of " Submarine Telegraphs," " The Story of the Atlantic Cable," etc., has written a collection of papers on " Good Causes " and combined them in a volume under the above title. Sir Charles includes some 46 examples of organisations whose objects are the sweetening of public life and the creation of a spirit of individual enterprise and mutual help and encouragement among those whose lives have not been cast in pleasant places.

The book is dedicated to the Prince of Wales and we can recommend it to all whose desire is to wipe out the reproach of our being a C3 nation. The publishers are George Routledge and Sons, and the price 4/6 net.

" The Flow and Measurement of Air and Gases." By A. B. Eason, M.A. Second edition revised. (London: Charles Griffin & Co., Ltd.). Pp. 254. 20/- net.

It is always a matter of interest to encounter a text-book written by a colleague, and Mr. Eason's work and experience with pneumatic tube systems in the Post Office is an assurance that anything he contributes to this subject would be valuable and authoritative.

The subject matter of this work is one in which an increasing amount of literature has been published in recent years and it is interesting to note that in preparing the present revised edition the author has consulted upwards of sixty text-books and over five hundred articles and reports.

The source of information are referenced very fully so that readers can readily consult the original articles when necessary.

As might be expected the results obtained by different workers under varying conditions are sometimes difficult to correlate, but the author has gone to considerable trouble in his efforts to do this and, wherever possible, has given the results of his own experience and measurements for comparison.

While it has not been found necessary to modify the portions of the book dealing with pneumatic tubes, since the essential principles remain the same, the author has taken the opportunity of providing fresh information regarding fresh developments such as automatic working.

Greater advances have been made in know-

ledge of the flow of gases through orifices and in the development of methods of measurement, and of recent years electrical methods have been successfully applied to this purpose. For example, electrical engineers have found it convenient to measure the losses in electrical machines by the temperature rise in the gases used for cooling the machines and for this purpose an accurate knowledge of the quantities of gases involved is essential. This method of determining losses has also been used in measuring the efficiency of high frequency apparatus where more direct methods cannot be applied. For such purposes electrical methods of determining the flow of large quantities of gases at low pressure seem to be particularly suited and it is therefore pleasing to note that such methods of measurement receive adquate treatment in this work.

It can be confidently predicted that this revised edition of Mr. Eason's book will find a large sphere of usefulness, not only to engineers engaged on pneumatic tube and compressed air problems, but to all other workers concerned with the flow of gases.

" Modern Radio Communication." By J. H. Reyner. Third Edition. (London: Sir Isaac Pitman & Sons, Ltd.). Pp. 260. Price 5/- net.

This book is intended to cover the syllabus of the City and Guilds examinations, the subject matter suitable for the Grade I. examination being in normal type, while matter required for the final examination is printed in smaller type or otherwise identified.

In this third edition opportunity has been taken to revise the subject matter in places and the present issue contains about 40 pages more than the previous edition.

The purpose of the book is reasonably fulfilled as regards the requirements for the Grade I. examination, but for the final examination the subject matter is scarcely sufficient, and in attempting to cover the whole scope of radio communication within the limits of this modest volume the author has set himself an almost impossible task.

One of the more serious omissions is the absence of any reference to the supersonic heterodyne method of reception, which is of great importance for commercial working, especially in the case of radio telephony because of its possibilities in selectivity.

In dealing with the subject of connection of radio telephone circuits to land lines a description is given of the Santa-Catalina installation which is over ten years old and now dismantled. Modern practice has led to many improvements which have been described from time to time in the technical press.

In dealing with call devices no reference is made to the marine automatic call devices now used on hundreds of vessels for registering distress calls. The author moreover suggests that all such devices are unreliable, costly and unlikely to be used, whereas in actual fact the use of such devices is rapidly increasing owing to the economies they permit in staff.

Chapter IX., dealing with the principles of radio communication, could be usefully revised in the light of modern practice and the use of short waves. The statement that the economic limit of aerial power on 600 metres wave-length is 6 K.W. is probably true as regards spark transmitters where the aerial is energized only for about 1% of the time. The statement is not true for undamped wave transmiters and a sriking example of this is the London National Broadcasting station with 68 K.W. aerial power working on the still lower wave-length of 261 metres.

In spite of these obvious deficiencies the book is an excellent little text-book for classes and private students, and attention is called to its defects in the hope that the author will take an early opportunity of rendering it still more useful.

A.J.G.

" Switchgear Practice." By Henry E. Poole, B.Sc. (London), A.M.I.E.E., A.C.G.I. Messrs. Chapman & Hall. Price 15/-.

This book as its name implies carries the reader over a wide range of switchgear in general use for power distribution. After describing and discussing the merits of various protection systems for localising faults which may arise on

power distribution networks the author includes a chapter on construction data in which in addition to the regulations laid down by B.E.S.A. he quotes those of V.D.E., the German Institution of Electrical Engineers, which go further than the former and include minimum clearances for the interior of oil switches and take into consideration the rupturing capacity as well as the rated volts in the design of the apparatus. The detailed construction of air and oil break switches is then considered with numerous illustrations, giving particulars of operating parts and also complete switches for use in connection with different voltages and loads. The various types of switchboards are then treated, including the panel type, open frame work, mild steel truck, and other removable units. Brickwork and concrete cells for switchgear is also dealt with. A chapter is also included describing switchgear for use in mines with examples of Continental as well as British practice. The book is well arranged and illustrated with a large number of examples of actual apparatus in use with a minimum of references to scientific theory. Since the advent of the British Grid System the necessity of providing switchgear with sufficient rupturing capacity to deal with the large amount of power involved when a serious fault occurs is of increasing importance and the book should appeal to all those interested in the design and operation of industrial and other types of switchgear.

H.B.C.

BOOKS FOR STUDENTS AND ENGINEERS

RELAYS IN AUTOMATIC TELEPHONY

By R. W. PALMER, A.M.I.E.E.

A thoroughly reliable and up-to-date book covering the syllabus of the City and Guilds Examination with respect to telephone relays.

Post Office Electrical Engineer's Journal says, "The text book should prove extremely useful not only to engineers engaged in the practical application of Automatic Telephony, but also to stu ents of the subject."

190 pp. **10s. 6d.** net. Illustrated.

ALTERNATING CURRENT BRIDGE METHODS

By B. HAGUE, D.Sc. (Lond.), D.I.C., A.C.G.I. For the measurement of Inductance, Capacitance, and Effective Resistance at Low and Telephonic Frequencies. The Book has been thoroughly revised and enlarged.

' No one who has to deal with a bridge can afford to be without this book." (*Journal of Scientific Instruments*).

SECOND EDITION. **15s.** net.

AUTOMATIC TELEPHONY SIMPLIFIED.

By C. W. BROWN, A.M.I.E.E., *Engineer-in-Chief's Department, G.P.O., London.*

Crown 8vo, cloth gilt, 180 pp., with 81 illustrations, Second Edition. **6s.** net.

PRIVATE AUTOMATIC BRANCH EXCHANGES.

By R. T. A. DENNISON., *of the Engineer-in-Chief's Office, G.P.O., London.*

Crown 8vo., cloth gilt, 304 pp., illustrated. **12s. 6d.** net.

THE DIRECTOR SYSTEM OF AUTOMATIC TELEPHONY.

By W. E. HUDSON, B.Sc., (Hons.) (Lond.), Whit. Sch., A.C.G.I., *Engineer- in-Chief's Department, G.P.O.*

Crown 8vo., cloth gilt, 166 pp., with 174 illustrations. **5s.** net.

THE CALL INDICATOR SYSTEM IN AUTOMATIC TELEPHONY.

By A. G. FREESTONE, *of the Automatic Training School, G.P.O., London.*

Crown 8vo., cloth gilt, 124 pp., illustrated. **6s.** net.

THE PRACTICAL TELEPHONE HANDBOOK AND GUIDE TO THE TELEPHONIC EXCHANGE.

By JOSEPH POOLE, A.M.I.E.E., Wh.Sc., in collaboration with other specialists in telephone engineering.

Crown 8vo, with 685 illustrations. Seventh Edition. **18s.** net.

Send for particulars of any of the above books, post free.

SIR ISAAC PITMAN & SONS, LTD., 39-41, Parker Street, Kingsway, London, W.C. 2

STAFF CHANGES.

POST OFFICE ENGINEERING DEPARTMENT.

PROMOTIONS.

Name.	From	To	Date.
Anson, B. O.	Assistant Staff Engineer, E.-in-C.O.	Staff Engineer, E.-in-C.O.	1-6-30
Woollard, F.	Executive Engineer, E.-in-C.O.	Assistant Staff Engineer, E.-in-C.O.	1-6-31
Maddock, G. M.	Executive Engineer, E.-in-C.O.	Assistant Staff Engineer, E.-in-C.O.	1-4-31
Hanford, S.	Assistant Engineer, E.-in-C.O.	Executive Engineer, E.-in-C.O.	4-1-31
Cave-Browne-Cave, Capt. N. F. ...	Executive Engineer, Testing Branch, Birmingham.	Assistant Suptg. Engineer, Eastern District.	1-4-31
Brocklesby, C.	Executive Engineer, S. Lancs. District	Assistant Suptg. Engineer N.E. District.	To be fixed later.
Morgan, C. E.	Assistant Engineer, S. Lancs. District.	Executive Engineer, N. East District.	25-12-30
Adams, W. J.	Chief Inspector, Testing Branch.	Assistant Engineer, Testing Branch.	13-2-31
Cooper, G. H. S.	Inspector, London District.	Chief Inspector, E.-in-C.O.	24-12-30
Whitehead, W. C.	Inspector, London District.	Chief Inspector, London District.	30-12-30
Longmore, F. W.	Inspector, E.-in-C.O.	Chief Inspector, E.-in-C.O.	24-12-30
Warne, G. C.	Inspector, London District.	Chief Inspector, London District.	28-9-30
Sard, P. J.	Inspector, London District.	Chief Inspector, London District.	1-1-31
Proctor, F. H.	Skilled Workmen, Cl. I., E.-in-C.O.	Inspector, E.-in-C.O.	4-10-30
Price, J. W.			22-6-29
Smith, E. R.			10-1-30
Oldacre, A. G.			25-5-30
Thomas, G. E. T.	Skilled Workmen, Cl. II., E.-in-C.O.		1-8-30
Pyrah, F.			8-11-30
Miller, R. W.	Unestablished Skilled Workmen, E.-in-C.O.		23-11-29
Belfit, F. W.	Skilled Workman, Cl. I., Scot. West District.	Inspector, Scot. West District.	25-10-30
Wade, W.	Skilled Workman, Cl. I., S. Wales District.	Inspector, S. Wales District.	27-8-30
Gill, W. E.	Skilled Workman, Cl. II., N. Mid-	Inspector, N. Mid. District.	To be fixed later.
Riddle, H.	Skilled Workmen, Cl. I., S. West District.	Inspectors, S. West District.	28-4-29
Wiltshire, R. E.			8-2-31
Nixon, J. L.	Skilled Workman, Cl. I., N. Mid. District.	Inspector, N. Mid. District.	To be fixed later.
Winter, J. L.	Skilled Workman, Cl. I., N. Ire. District.	Inspector, N. Ire. District.	16-8-30

RETIREMENTS.

Name.	Rank.	District.	Date.
Platt, W.	Executive Engineer.	N. East.	22-12-30
Henrici, R. C.	Assistant Engineer.	S. Wales.	26-12-30
Davies, E. I. S.	Chief Inspector.	,,	4-12-30
Barclay, W.	Inspector.	Scot. West.	31-12-30
Connacher, A. H.	,,	,,	31-12-30
Young, J. A.	,,	London.	18-12-30
Guile, T. H.	,,	S. East.	31-12-31
Chadd, C. A.	,,	London.	31-12-31
Stewart, W. W.	,,	N. Mid.	31-12-31
Ellison, F.	,,	S. Lancs.	31-12-31
Aked, J.	Chief Inspector.	S. Mid.	26-1-31
Eager, H. C.	2nd Class Engineer.	Testing Branch.	10-1-31
Carr, E. R.	Inspector.	London.	3-2-31
Woods, A.	,,	N. East.	31-1-31
Jones, T. V.	Assistant Engineer.	London.	31-1-31
Pollock, C. E.	,,	N.	31-1-31
Bassett, S. W.	Executive Engineer.	E.	3-3-31
Leigh, J. H.	,,	S. Lancs.	5-3-31
Wilkinson, E.	Inspector.	N.E.	28-2-31

APPOINTMENTS.

Name.	From	To	Date.
Gill, C. J.	Probationary Inspectors.	Inspectors.	1-12-30
Markby, E. J.			
Horner, F. H.			
Holloway, A.			
Edwards, W. K.			
Devey, G. B.			
Blight, A.			
Westcott, A. G. B.			
Gormley, L. V.			
Moore, G.			
Latimer, E. D.			
Rimes, R. E.			
Howell, L. T.			
Coates, G. H.			
Crook, H. G.			
Lee, W. H.			
Hawking, W.			
Kirkham, W. D.			
Stevens, P. F.			
Blair, D. C.			
Hunt, A. H. F.			
Brown, H. R.			
Gosling, F.			
Vann, C. J.			
Millen, G. J.	Limited Competition.	Probationary Assistant Engineers.	1-1-31
Boocock, R. O.			
Anderson, E. W.			
Perryman, C. F.			
Robinson, A. K.			
Couch, P. R.			
Helman, S. L.			
McMillan, D.			
Knapman, D. E.			
Hunt, R. H.			
Knox, A. H. C.			
Tobin, W. J. E.	Open Competition.	Probationary Assistant Engineers.	7-1-31
Rousell, S. M. E.			7-1-31
Lewis, N. W. J.			
Dickson, E.			1-1-31
Leigh, H.			
Cook, A.			
Lucas, F. N.			
Calveley, C. E.			
Pitcairn, A. C			

DEATHS.

Name.	Rank.	District.	Date.
Alexander, R.	Assistant Superintending Engineer	N. East.	27-12-30
Chapman, E. J.	Inspector.	London.	5-1-31
Akehurst, R. G.	,,	,,	11-1-31
Smith, W. E.	Chief Inspector.	,,	12-1-31
Booth, W. J.	Inspector.	S. Lancs.	14-1-31
Sperrey, H.	,,	London.	28-1-31
Holder, W. S.	,,	S. West.	27-1-31
Aked, G. F.	,,	N. Mid.	24-2-31

REVERSION.

Name.	From	To	Date.
Lambert, S.	Chief Inspector, N. Wales District.	Inspector, N. Wales District.	21-12-30

TRANSFERS.

Name.	Rank.	From	To	Date.
Hay, P. G.	Assistant Engineer.	London.	S. East.	4-1-31
Baines, J.	,,	E.-in-C.O.	N. East.	15-2-31

CLERICAL ESTABLISHMENT.

PROMOTIONS.

Name.	Rank.	District.	Promoted.	District.	Date
Gerke, J. J.	Clerical Officer.	L.E.D.	Higher Clerical Officer.	L.E.D.	23-7-30
Gardiner, H.	,,	L.E.D.	,,	L.E.D.	16-12-30
Denton, J. C.	Higher Clerical Officer.	N. East.	Staff Officer.	Eastern	1-1-31
Davies, E. R.	,,	S. Wales.	,,	S. Lancs.	4-1-31
Bullock, C.	Clerical Officer.	N. Mid.	Higher Clerical Officer.	N. Mid.	23-7-30
Franklin, G. W.	,,	Eastern	,,	Eastern	1-1-31
Brown, H.	,,	S. Lancs.	,,	S. Mid.	11-1-31
Tyler, J. T.	,,	N. Mid.	,,	N. Mid.	9-8-30
Preston, ●.	,,	S. Lancs.	,,	N.	1-1-31
Colman, W. A	,,	N. Mid.	,,	S. Eastern	1-1-31
Wilson, E.	,,	Eastern	,,	S. Mid.	1-1-31

RETIREMENTS.

Name.	Rank.	District.	Date.
Powell, G. T.	Staff Officer.	S. Wales.	3-1-31
Rankin, W. H.	Higher Clerical Officer.	N. Mid.	13-2-31
Matthews, T. E.	,,	S. Lancs.	21-2-31
Crawford, G. W. J.	Staff Officer.	Scot. West.	31-3-31
Smith, H. S.	Higher Clerical Officer.	London.	31-1-31

BOARD OF EDITORS.

B. O. ANSON, M.I.E.E., Chairman.

P. J. RIDD, M.I.E.E.

H. KITCHEN, M.I.E.E.

A. J. GILL, B.Sc., M.I.E.E., M.I.R.E.

J. PRESCOTT.

E. H. M. SLATTERY.

W. CRUICKSHANK, M.I.E.E., Managing Editor.

J. J. McKICHAN, O.B.E., A.M.I.E.E., Assistant Editor.

COMMUNICATIONS.

All Remittances and Communications should be addressed to the MANAGING EDITOR, P.●.E.E. JOURNAL, Engineer-in-Chief's Office, Alder House, London, E.C.1.

Binding covers and copies of the Contents for Vol. 3 to 23 are available, and may be obtained from the local agents for 1*s.* 6*d.* and 3*d.* respectively. Subscribers can have their copies of Vol. 23 bound, with index included, at a cost of 3*s.*, by sending the JOURNALS to the local agents. Orders for bindings, Vols. 1—19, should indicate whether the original binding with black lettering, or the latter pattern in gold, is required. Covers with gold lettering will be the only type stocked from Vol. 20 onwards.

The price of the JOURNAL is 1*s.* (1*s.* 3*d.* post free) per copy, or 5*s.* per annum, post free. All back numbers 2*s.* each.

THE
Post Office Electrical Engineers' Journal

MICHAEL FARADAY.

THIS year is a notable one in the history of electrical engineering, inasmuch as it marks the centenary of the discovery of electro-magnetic induction—one of the greatest events in the annals of science. This momentous discovery was made by Michael Faraday on August 29th, 1831, after years of patient research in the laboratory of the Royal Institution in Albemarle Street, London.

It may be said of Faraday that he is one of the great figures in history, one of a small and select company of philosophers who have contributed much for the benefit of mankind. Faraday's epoch-making discoveries in chemistry and electricity form the basis of manifold applications of science in the modern world. Electric lighting and power, telegraphy, telephony and radio on the electrical side, trace their development from his fundamental discoveries.

There was an amazing and diversified genius in Michael Faraday. Many examples could be quoted in support of this statement in the realms of Chemistry, Optics, and Magnetism. Space will not permit of more than a passing reference to two of these. He succeeded in separating the solvent known as Benzine or Benzol, which is now the basis of a great industry. His fundamental research work in alloying iron with minute quantities of nickel, silver, and platinum, pointed the way to the discovery of stainless steel.

Faraday spent 50 years of his life in the service of the Royal Institution, which was founded in 1800 for the advancement of natural knowledge. In general, the objects of the Royal Institution are to prosecute scientific and literary research, to illustrate and diffuse the principles of inductive and experimental science, to give opportunities for social intercourse among those who are attached to science, and to afford them the means of collective and individual study. It is fitting in every way therefore that the " Royal " should take the lead, and be seconded by the Institution of Electrical Engineers, in arranging a series of centenary celebrations in London, which will do honour to the work of an Englishman whose memory is held in love and respect in every part of the world.

Michael Faraday started life from humble beginnings; he was born in Newington Butts in 1791, the son of a blacksmith. He became an errand boy at a newspaper shop at the age of 13 and a year later was apprenticed to a bookbinder in Blandford Street, Marylebone. The bookbinder's shop stood near the rear of Hertford House, Manchester Square, the home of the famous Wallace Collection. A tablet on the wall of the shop records the fact that Faraday worked there for nine years.

Scientific books which came into his hands for binding purposes gave him opportunities to increase his store of knowledge. He bound books as a duty, he read them as a joy. It has been recorded by Magrath, Secretary of the Athanæum, that, entering the bookbinder's shop on one occasion, he found one of the young apprentices absorbed in the study of a book when he ought to have been binding it. The

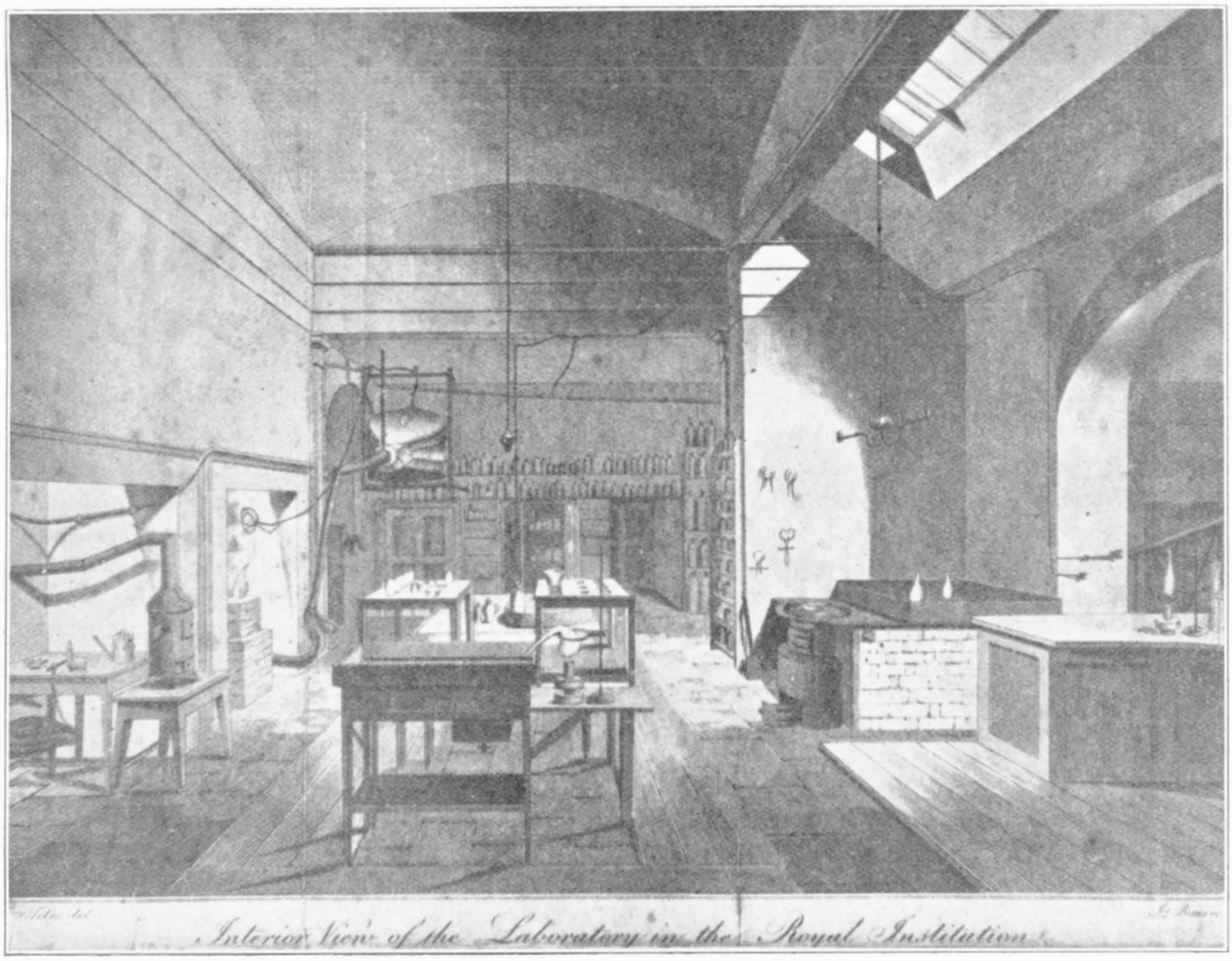


FIG. 1.

From a drawing by W. Tite.

two entered into conversation and Magrath was astonished to find that he was speaking with "a self-taught chemist of no slender proportions."

Faraday as a youth was particularly interested in chemistry and electricity and all the books on these subjects that came into his hands, whether for binding or as loans from friends, or finally, as purchases from his own slender means, were studied with the deepest interest and also made the basis of careful notes.

At this period in his life, he wrote to one of his friends "I loved to read the scientific books which were under my hand, ... I made simple experiments in chemistry as could be defrayed in their expense by a few pence per week and also constructed an electrical machine, first with a glass phial and afterwards with a real cylinder, as well as other electrical apparatus of a corresponding kind."

In 1812 Faraday was able, by borrowing a shilling from his brother,—a plumber—to attend one of Sir Humphrey Davy's lectures at the Royal Institution. This and the succeeding lectures made a great impression on Faraday's mind;—he compiled careful notes, made a fair copy and bound the beautifully written pages into a volume which he sent to Davy. This book is now in the Royal Institution and is one of its most cherished possessions. Faraday was fired with a desire to become a scientific assistant and the sending of his notes to Davy was accompanied by a request that some form of employ-

ment might be found for him. By a fortunate circumstance, both to Faraday and to the world in general, a vacancy occurred which enabled the youth to be employed as a laboratory servant at the Royal Institution at a weekly wage of 25/-, the position also including two rooms in the Institution building. This was the beginning of Faraday's career as a philosopher and scientist and, in the quiet laboratories in Albemarle Street, he helped Davy to continue his investigations in chemistry.

Through the courtesy of the officers of the Royal Institution, permission has been given to the writer to reproduce several interesting pictures bearing directly on Faraday and his work. Fig. 1 is a view of the interior of the Institution laboratory as it appeared in 1816, from a drawing by W. Tite. It will be noticed that the room is very sparsely equipped and the arrangement of the bellows and furnace is reminiscent of the blacksmith's forge.

Fig. 2. Faraday in 1831.

From a painting by H. W. Pickersgill, R.A.

Fig. 2 is a reproduction of a painting by H. W. Pickersgill, R.A., of Faraday as he appeared in 1831, the year which probably marked the zenith of his career as a discoverer.

Fig. 3 is a copy of an actual photograph from life, taken when Faraday was about 60 years old.

There is a special interest associated with the picture of one of the Juvenile Christmas lectures in December, 1855, painted by Alexander Blaikley, Fig. 4. This shews Michael Faraday lecturing on "The Metals." The Prince Consort is in the chair and the Prince of Wales, (the late King Edward VII.) is sitting on the left side of his father, with Prince Alfred (Duke of Edinburgh) on the right. Among the young people present at this lecture was Alfred Yarrow, now Sir Alfred Yarrow, the famous shipbuilder, who, together with Sir James Crichton-Browne, are probably the last remaining links with that historic meeting. Sir Alfred, in an interview granted to the writer of these notes, states that as a boy of 13 he attended the Juvenile lectures and was present on the occasion when the Prince Consort was in the chair. After each of the lectures, Faraday usually invited a number of the boys to join him in the laboratory, where he would carry out experiments and give demonstrations for the benefit of the youngsters, and also allow the boys to share in the general delight of experimental work. Alfred Yarrow attended these and other lectures at the Royal Institution during a period of ten years and had many opportunities of conversing with the eminent philosopher.

The Post Office has an association with Michael Faraday's life which may also be regarded as unique in Service annals. It is true that the link was forged originally by colleagues in the National Telephone Company, prior to the transfer of that undertaking to the State. The link remains to this day as a memorial and is a source of special pride to members of the electrical engineering profession. In 1899, the N.T. Coy. purchased a building in Barnsbury which had hitherto been used as a place of worship and, in due course, the building became known as the North telephone exchange. In Sylvanus Thompson's admirably written "Life of Faraday" there is a reference to a Sandemanian Meeting House in North London which Faraday attended. Careful investigations were made and it was ascertained beyond doubt that the North exchange and the old chapel were one and the same building. One of the trustees of the chapel was also able to supply information

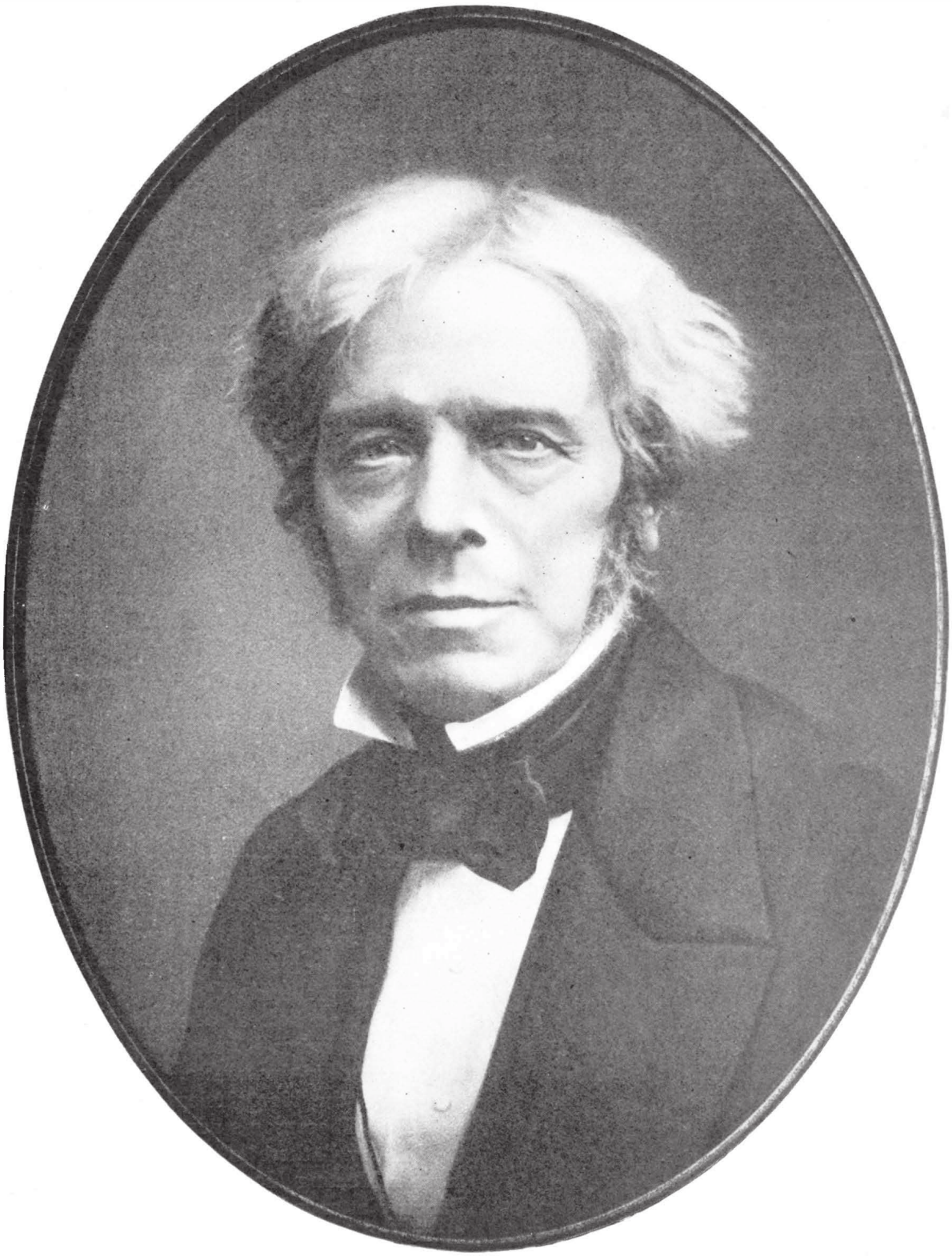


FIG. 3.—MICHAEL FARADAY, FROM A PHOTOGRAPH WHEN HE WAS ABOUT 60 YEARS OLD.

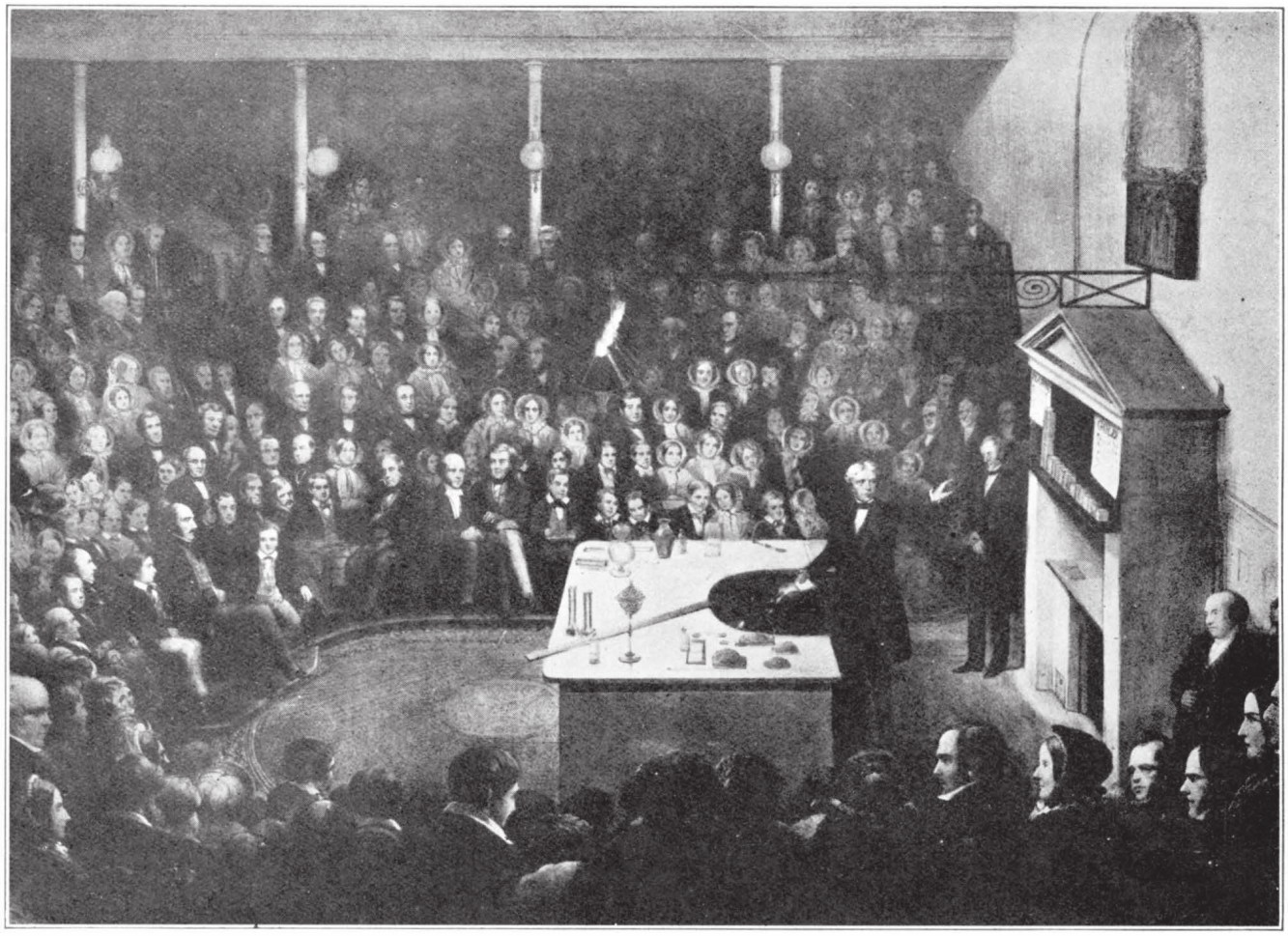


FIG. 4.—FARADAY LECTURING AT THE ROYAL INSTITUTION ON 27TH DECEMBER, 1855.
From a painting by Alexander Blaikley.

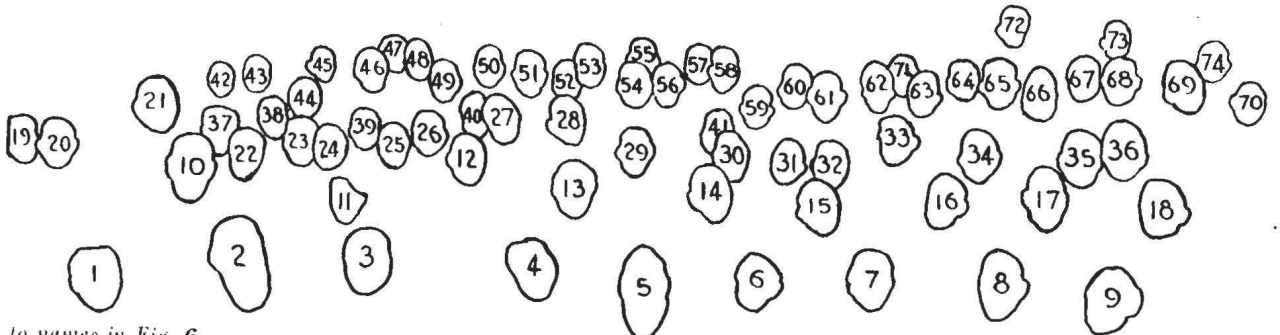
concerning Faraday's seat on the platform whilst serving as an Elder, also the position of his pew in the body of the hall.

Young Alfred Yarrow lived at that time in Arundel Square, Barnsbury, within a stone's throw of the chapel. Faraday was one of Yarrow's heroes and it was customary for he and a boy friend to way-lay Professor and Mrs. Faraday as they were walking to chapel along the Caledonian Road, doff their caps and say "Good afternoon, Professor." Faraday had always a kindly word for the boys. Not content with one greeting, the boys would then find their way to the chapel by another route and repeat the salutation! Yarrow and his friend attended service on several occasions and heard the Professor read the portion from the Scrip-

ERECTED BY THE
STAFF OF THE
NATIONAL TELEPHONE COMPANY LIMITED.
TO COMMEMORATE THE FACT THAT
MICHAEL FARADAY USED TO WORSHIP HERE
FROM 1862 TILL THE DATE OF HIS DEATH IN 1867
FROM 1862 TO 1899 THIS BUILDING WAS
THE MEETING HOUSE OF THE SANDEMANIANS
OF WHICH BODY MICHAEL FARADAY WAS AN ELDER
THIS PLATE MARKS THE POSITION
WHICH HE USUALLY OCCUPIED ON THE PLATFORM
THE POSITION OF HIS PEW IS INDICATED BY
A PLATE ON THE FLOOR
UNVEILED BY THE
RIGHT HON. LORD KELVIN O.M., P.C., G.C.V.O., F.R.S., L.L.D., &c.
24TH NOVEMBER 1906

FIG. 5.—FARADAY MEMORIAL TABLET FITTED IN WALL OF SWITCHROOM OF NORTH TELEPHONE EXCHANGE, LONDON.

FIG. 6.—UNVEILING OF THE FARADAY MEMORIAL AT NORTH TELEPHONE EXCHANGE BY LORD KELVIN, 24TH NOVEMBER, 1906. (Photograph reproduced from the National Telephone Journal, January, 1907).



Key to names in Fig. 6.

1 Miss K. Barnard (Niece of Faraday).
2 Sir Joseph Swan.
3 Sir A. K. Rollit.
4 Lady Kelvin.
5 Lord Kelvin.
6 Miss Barnard (Niece of Faraday).
7 H. Faraday (Nephew of Faraday).
8 Sir R. T. Glazewood.
9 Dr. Sylvanus P. Thompson.
10 C. J. Phillips.
11 Miss Swan.
12 A. F. Blaikley.
13 J. Barnard (Nephew of Faraday).
14 Dr. Walmsley.
15 H. E. Harrison.
16 S. J. Goddard.
17 F. Gill.
18 C. Elliott.
19 H. Honor.
20 J. Sandell.
21 C. B. Clay.
22 F. C. Raphael.
23 I. H. Jenkins.
24 T. Mather.
25 F. Francis.
26 H. Comer.
27 W. Guy.
28 A. P. Trotter.
29 J. E. Kingsbury.
30 A. Coleman.
31 W. M. Mordey.
32 E. Laidlaw.
33 W. W. Cood.
34 J. F. Edmonds.
35 S. J. Smith.
36 H. Davis.
37 T. Fletcher.
38 H. C. Gray.
39 Dudley Stuart.
40 P. T. Wood.
41 W. Judd.
42 Miss Hughes.
43 Miss Ashmead.
44 W. H. U. Napier.
45 W. D. Stewart.
46 W. M. France.
47 A. J. Aldridge.
48 O. S. Stiles.
49 R. H. Williams.
50 J. R. Gall.
51 H. Bines.
52 B. S. Cohen.
53 W. Ireland.
54 A. Warner.
55 W. U. Lonner.
55 J. H. Watkins.
56 W. U. Lonnon.
57 N. McLeod.
58 G. F. Greenham.
59 C. T. Peacock.
60 F. Woollard.
61 J. Poole.
62 G. H. Bryant.
63 J. Ashton.
64 G. Maddock.
65 J. Wolff.
66 H. S. Thompson.
67 P. Prentice.
68 P. H. Cole.
69 H. Bruce.
70 T. W. Woodman.
71 J. Ashton, junior.
72 G. H. Bush.
73 J. Teeboon.
74 G. McGregor.

tures or give the short address. The order of service was very similar to that conducted by the Society of Friends.

To mark the association of the North exchange building with Michael Faraday, the staff of the National Telephone Company subscribed to a fund for the provision of a memorial. This consists of a bronze plate fitted into the wall, also a small octagonal bronze plate fixed on the floor. The first marks the position Faraday occupied when on the platform, and the latter, which bears the initials " M.F.," the position of his pew. The memorial was unveiled by Lord Kelvin on Saturday, 24th November, 1906, in the presence of a distinguished and representative company. A full account of the proceedings is published in the National Telephone Journal for January, 1907. The event has historical interest, not only because of the honour paid to a great man by other eminent scientists and engineers, but because relatives of the Faraday family were present. An illustration of the memorial tablet is shewn in Fig. **5**, whilst a photograph of the group attending the unveiling ceremony is shewn in Fig. **6**. A key giving the names in the group accompanies Fig. **6**, but even without this guide it is easy to pick out faces that are recognizable and well known, even after the passage of a quarter of a century!

As an indication of Sir Alfred Yarrow's great regard for Michael Faraday, it is of interest to record that the commemorative tablets at the North exchange are being reproduced in bronze and will be presented to the Council of the Royal Institution.

Sir William Bragg who, as Fullerian Professor of Chemistry at the Royal Institution, and Director of the Davy-Faraday Research Laboratory, holds two of the posts which Michael Faraday once filled, has, in a recent address, expressed in eloquent language the debt we owe to the great experimental philosopher:—

" It is Faraday's public life that belongs to us: it is one of the possessions of the nation, one of the great treasures. It is not only that his work has had such far-reaching consequences that all the world is affected by what he did, not only that he made plain the intricate connection between electricity and magnetism so that we are in daily dependence upon these forces of Nature for the transfer of power and intelligence; it is not only that on his discoveries are now resting great British industries which are alive and are helping us through these difficult times. All these things are marvels so that we are proud of our famous countryman. But we all love the man himself for his simplicity of faith and purpose, for the breadth of his vision and the humility of his thought, for his kindly generosity and for the light which he shed around him. He thought first of the quality of that which he gave, and only in the second place of that which he received in return. Could there be a nobler leading? Could there be any following more certain to bring us through times of depression and doubt to a triumphant ending? "

ANDREW GIBBON.

AN ALL-MAINS TELEPRINTER DUPLEX SET.

Capt. A. ARNOLD and A. E. DENMAN.

MOST readers will be familiar with the " All-Mains " wireless set. The main feature of such set is that the whole of the power required for the operation of the set is switched on or off by means of a single switch. This article describes a Teleprinter Duplex Set, developed by the Post Office Research Section, for which the power required for the Teleprinter motor, the line circuit, local circuit and auxiliary circuit is derived from the public alternating current mains and all batteries are eliminated.

The alternating current from the mains must of course be rectified and the introduction of the copper-oxide metal rectifier has provided a very suitable means. The use of these rectifiers has already become so general for radio work and the important and exacting work of railway signalling that it is not considered necessary to deal here with the interesting but lengthy subject of the characteristics of this type of rectifier.

The power-supply requirements of a Teleprinter duplex circuit may be divided into two

parts: (1) the power for driving the motor, (2) the power for line, local and auxiliary circuits.

The rectifier unit used was manufactured by the Westinghouse Brake and Saxby Signal Co., Ltd., to a specification designed to meet certain requirements indicated by preliminary experiments. The unit has a rated output of 110 volts, 0.75 ampere (D.C. mean). A schematic diagram of the unit is shown in Fig. **1**. Alternating current is supplied to the unit *via* the transformer. The rectifying elements are arranged in the Grätz bridge manner and each element, made in the form of a washer $1\frac{1}{2}$ inches in diameter, has a cooling fin. Since the voltages of the public supplies differ throughout the country, the turns ratio of the primary and secondary windings of the transformer must be such as to give a fixed voltage across the secondary winding on normal load, whatever the mains voltage may be. A secondary voltage of 153 has been fixed in the present case. Two types of unit are made, one for 100-120 v. mains and the other for 200-240 v. mains, with tappings on the primary windings of the transformers to provide for adjustment within the ranges. The output voltage and current values of a typical unit are shown in Fig. **2**. More detailed values are shown in the following table for an output range of from 100

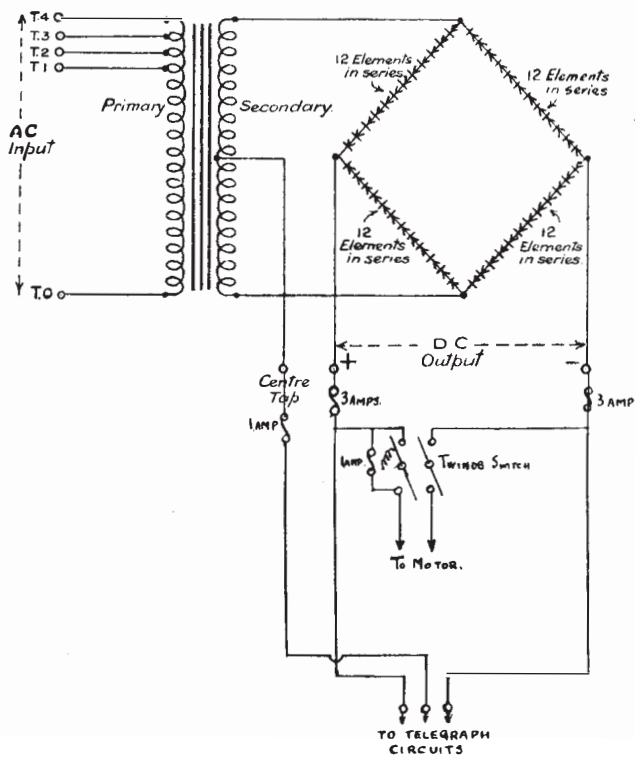


Fig. 1.—Rectifier Unit.

Teleprinter 3A motor circuit is shown in Fig. **4**. The initial current at starting is much greater than the normal running current. When rectifiers are used the initial current is not so

A.C. Input.				D.C. Output.				
Primary.		Secondary.		Volts	Current (m.a.'s)		Ratio $\frac{7}{6}$	Ratio $\frac{4}{7}$
Volts Vp	Current mAs. Cp	Volts Vs	Current mAs. Cs	(mean) Vo	Mean Co	R.M.S. Co		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
220	140	147	145	117	100	112.5	1.125	1.28
,,	170	147	210	116	150	170	1.133	1.23
,,	205	147	265	114	200	240	1.2	1.1
,,	245	147	320	113	250	300	1.2	1.066
,,	275	147	375	112	300	345	1.15	1.08
,,	310	146	437	111	350	420	1.2	1.04
,,	345	146	480	109.5	400	480	1.2	1.0
,,	380	146	550	109	450	550	1.22	1.0
,,	401.5	146	610	107.5	500	610	1.2	1.0
,,	490	146	750	105.5	600	750	1.25	1.0

to 600 milliamperes (D.C. mean), the circuit of Fig. **3** referring. The schematic diagram of a great as with secondary cell supply because the internal resistance of the rectifiers enters into the

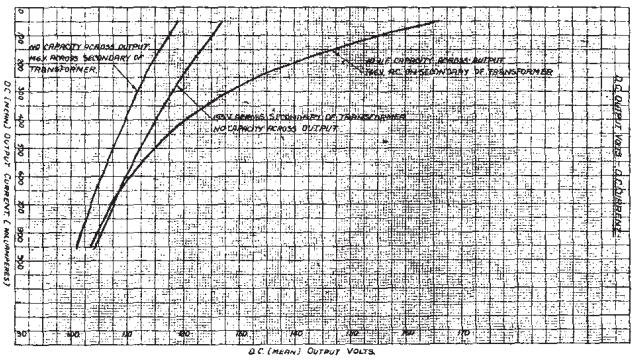

NO CAPACITY ACROSS OUTPUT
HALF ACROSS SECONDARY OF TRANSFORMER
FULL CAPACITY ACROSS OUTPUT
HALF A.C. ON SECONDARY OF TRANSFORMER
FULL ACROSS SECONDARY OF TRANSFORMER
NO CAPACITY ACROSS OUTPUT
D.C. OUTPUT (MEAN) CURRENT (MILLIAMPERES)
D.C. OUTPUT VOLTS (MEAN)
D.C. (MEAN) OUTPUT VOLTS

FIG. 2.—OUTPUT VOLTAGE AND CURRENT FROM A TYPICAL UNIT.

circuit. In the case of the Teleprinter No. 3A the starting current on switching on is about five amperes with secondary cells, and about three amperes with rectifiers. The motor attains its normal speed almost instantly in the secondary cell supply case, but not in the rectifier case. However, with a transformer secondary voltage of 153 volts and the field circuit resistance A, Fig. **4**, not greater than 250 ohms, no difficulty is experienced in cold weather, after the machine has been stopped for 12 hours, in obtaining normal speed within 4 seconds of switching on. With the same conditions regarding secondary voltage and field circuit resistance, no difficulty is found in adjusting the motor to the standard speed within the range of adjustment of the governor, and the teleprinters are interchangeable on the same unit, on different units, and on circuits driven from secondary cell supplies, without readjustment of speed.

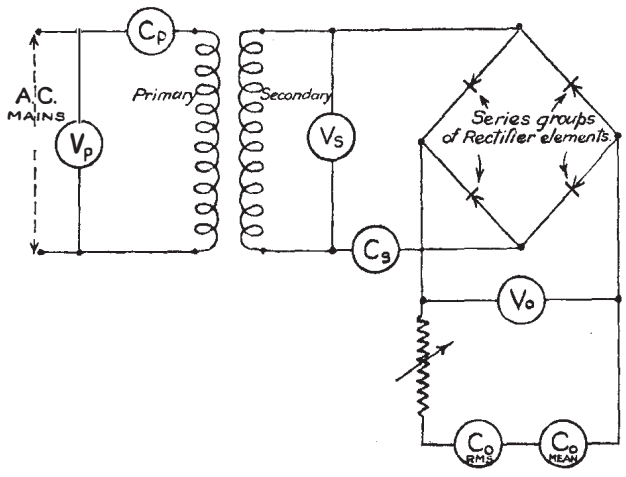


FIG. 3.—CIRCUIT OF FIG. 2.

A characteristic in connection with the driving of a shunt-wound motor from the rectifier is that the voltage across the output terminals is considerably greater than with an equivalent pure resistance load. The motor is a 110 v. D.C. motor and takes a current of from 0.4 to 0.6 amperes. The D.C. mean voltage output of the rectifier for 0.5 amperes, on a pure resistance load, is shown in Fig. **2** to be 107.5 volts. The D.C. mean voltage across the rectifier output terminals with the motor running is about 130 volts. This may lead to some confusion in practice and so a 10 μF condenser is connected across the output terminals. This reduces the voltage to 115 v. approximately. This condenser has other advantages described later. A

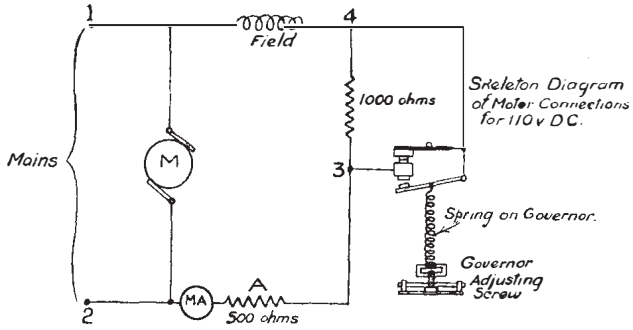


FIG. 4.—TELEPRINTER NO. 3A, SKELETON DIAGRAM.

further point of interest is that if there be any unsteadiness in the speed of the motor when supplied from secondary cells the speed is much steadier when driven from the rectified supply. This may be seen very easily if a tachometer be used for measuring the speed. It may be added that the use of a tachometer for testing and checking Teleprinter motor speeds is a very ready and reliable means. The speeds of the various spindles in a Teleprinter 3A are shown in Fig. **5**. Further, if a slot or hole be made in the cover opposite the centre of the governor disc, the speed may be checked without opening up the machine and removing the message tray, etc.

If the above conditions regarding the resistance in the field circuit is observed, the mains voltage in a certain typical case was varied from 200 v. to 230 v. without any change in the speeds of six machines. The legal requirements imposed on Supply Undertakings ensure that these

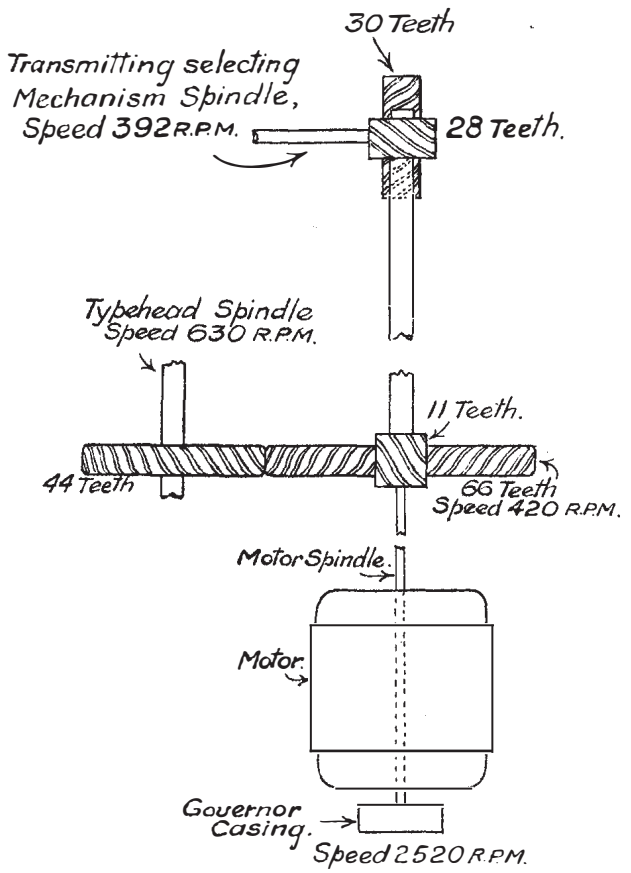


FIG. 5.—SPEEDS OF MAIN SPINDLES.

variations will normally be within small limits and a variation of 5% from a mean value is the maximum observed during trials at various offices.

The motors do not heat up more on rectified A.C. supply than with D.C. supply and no difference in commutator sparking is seen.

Where the public mains supply is A.C. it has been decided to use rectifiers and D.C. motors, the advantages being:—

(1) A.C. motors require considerable maintenance and in some cases are totally unsatisfactory.

(2) Considerable economy due to standardisation of one type of D.C. motor for all machines. This is a very important factor.

Supply of Line and Local Currents.—The maximum voltage available is that across the output terminals when the motor is running. To provide for double current working two equal voltages are obtained for the rectifier by the method, patented by Mr. Stevens, of the Westinghouse, Brake and Saxby Signal Co. This method is shown in Fig. 1 and will be seen to consist of using the Grätz Bridge and taking a tapping from the centre points of the transformer secondary. It will be seen that the voltage obtained will be half the full voltage across the output terminals.

Wave form of output current.—The wave form of the output current of copper oxide rectifiers is nearly a perfectly rectified input wave, neglecting any distortion of wave form due to the presence of the rectifiers. The resulting rectified wave form from a sine wave input is therefore a pulsating, unidirectional wave, having a number of loops or phases equal to twice the frequency of the input wave. It can be shown by analysis that such a pulsating wave may be made up from the following components:

(1) A steady current of 63.6% of the maximum value.

(2) A sinusoidal wave of frequency $2f$ and amplitude equal to 42.4% of the maximum value.

(3) A sinusoidal wave of frequency $4f$ and amplitude equal to 8.5% of the maximum value.

(4) A sinusoidal wave of frequency $6f$ and amplitude 3.6% of the maximum value.

Where f is the frequency of the input sine wave. The component frequencies higher than $6f$ have such small amplitudes that for the present case they may be neglected. In the present case the output wave is also affected to some extent by the motor circuit.

It is desirable to smooth such an output current for the following reasons:—

(1) Liability of causing interference in neighbouring telegraph and telephone circuits.

(2) With unsmoothed current, there is a liability to experience difficulty in obtaining a telegraph duplex balance. This would be increased if the supply frequencies at the terminals were different.

(3) A pulsating line current would be unsuitable for " G " relay reception.

The desirable features of a smoothing circuit for a duplex circuit are:—

(1) Minimum D.C. resistance.

(2) Absence of disturbing effect on the duplex balance.
(3) Economy in apparatus and space.
(4) Minimum reduction in the telegraph transmission efficiency of the circuit.

Various types of smoothing circuits have been tried, each possessing certain advantages. The required smoothing is obtained, with the least cost and amount of apparatus, if the filter be made so that the higher frequencies are eliminated and the remaining ripple reduced in magnitude as far a possible with a reasonable amount of apparatus consistent with the retention of good telegraph transmission. An important consideration is that in most cases in practice a smoother (or filter) would be inserted in the telegraph circuit to reduce or eliminate interference in adjacent circuits, and also a spark quenching device. If such a filter and spark quench circuit were provided, in addition to the rectifier and smoother, a considerable amount of apparatus would be needed. It appears desirable therefore to combine in the apparatus necessary for smoothing the rectifier supply, the functions of—

(1) A smoother for the rectified current.
(2) A line filter.
(3) Spark quench circuits.

The type of smoother adopted and the manner in which it is inserted in the telegraph circuit is shown in Fig. **6**. The inductance coil has a D.C. resistance of 20 ohms and an inductance of 2 Henrys.

This was tested in underground circuits for interference on adjacent telephone and telegraph circuits under conditions much more severe than would arise in practice and was found very satisfactory.

Local Circuits.—No smoothing is required for the local current, whether the Teleprinter relay coil or the Sounder is in circuit. To ensure safe operation of the Teleprinter relay under all conditions, however, it is desirable to use " E " type relay coils (100 + 100 ohms resistance, 6 H. inductance) with one magnet instead of the " C " type coils (25 + 25 ohms, 2 H.) because of the greater magnetic effect and the smoothing effect of the higher inductance.

Auxiliary Circuit.—Where a " G " relay is used as a line relay, it is necessary to ensure an adequate degree of smoothing through the

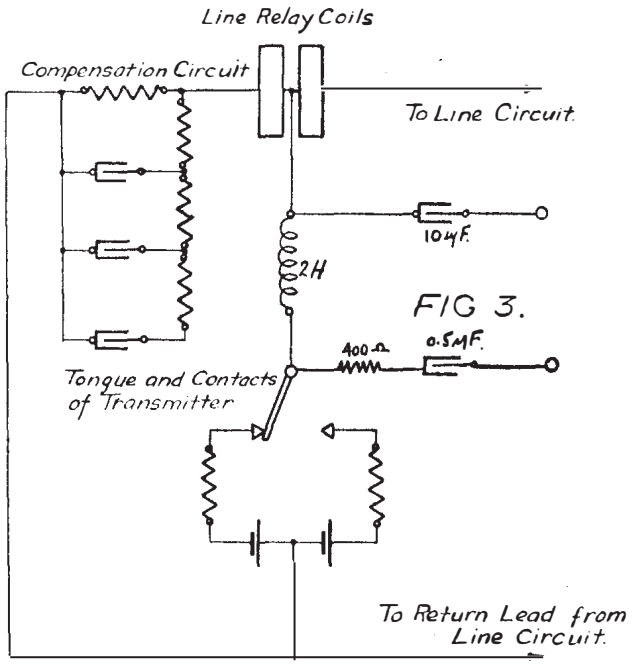


FIG. 6.—SMOOTHER ARRANGEMENT.

auxiliary circuit. This is very conveniently achieved without any extra apparatus by arranging the circuit as shown in Fig. **7**. It will be seen that the Teleprinter relay coils and the condenser F form an effective filter for current into the coils of the " G " relay. The condenser usually placed in the base of the Teleprinter machine and connected in parallel with the relay coils is omitted. In some cases the resistance E could be omitted, but it is used to ensure a satisfactory minimum operating current for the Teleprinter relay and render its operation independent of any " G " auxiliary circuit adjustments.

At duplex it will be understood that the transmitter tongue may make contact either with the same pole, or with the opposite pole, as that with which the line receiving relay tongue is in contact. If the line receiving relay be held on one contact and the transmitter tongue moved from one pole to the other, a change in the value of the current in the local circuit is observed, viz., from 20 mA to 24 mA. Or, if under the same conditions a voltmeter be connected across either terminal of the D.C. output of the rectifier and its centre point, a change in voltage from 57 v. to 64 v. is observed. Even under working conditions understood to be

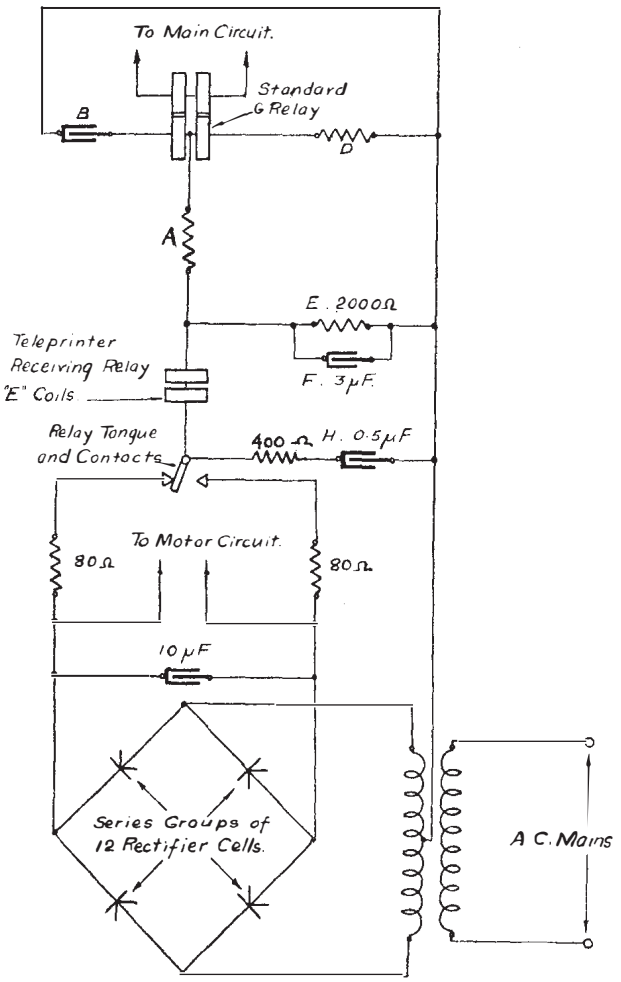


FIG. 7.—USING "G." RELAY.

exacting, this change did not affect operating. This effect can, however, be reduced to a "kick" only of 1.0 milliampere by connecting a condenser of suitable capacity across the output terminals of the rectifier. A condenser 4 μF is usually sufficient for this purpose, but in most cases this causes another variation. Without a condenser across the output terminals of the rectifier, and the motor running, the mean D.C. output volts may be between 120 v. and 130 v., according to the machine in use. When the receiver is printing, this voltage rises about 3% or 4%. If a condenser of 4 μF be connected across the output terminals, the total voltage is reduced by 15 or 20 volts, but in most cases rises by the same amount when the receiver prints. If, however, the capacity of the condenser be increased to 8 or 10 μF, this large increase on printing is reduced to about 3% in all cases and the D.C. output voltage of the rectifier corresponds very nearly to the normal output voltage with a pure resistance load taking a similar value of current to that taken by the motor. There is a certain optimum value for the condenser across the rectifier output terminals in order to reduce the interaction between line and local circuits to a minimum. This value depends on the characteristics of the line circuit in use, but has been between 8 μF and 10 μF in all cases observed and a value of 10 μF has been fixed.

When the motor is not running, the circuit conditions are altered, but not sufficiently to interfere with key duplex. Since, however, the normal condition of the circuit is with the motor running, no attempt is made to balance except when the motor is running. Balancing is effected with the relevant switches to "Morse" and to "Sounder" and either to "Resistance" at the distant end or to currents or to both in turn, exactly as with all ordinary duplex circuits. The battery "Resistance" value, obtained by adjusting it until the balance to currents was the same as the balance to "Resistance," was 60 ohms.

Previous reference has been made to variations in mains supply: it is only necessary to add that the change in the output voltage of the rectifier is proportional to the change in the mains voltage and that since the voltages in this case are obtained by connection to the centre of the total voltage output, bias cannot arise due to unequal voltages even if the mains voltage does vary.

The fuses provided are a 3 amps (R.C.) in each of the leads from the positive and negative output terminals, for the protection of the leads to the motor circuit, and a 1 amp (R.C.) fuse in the centre lead for the protection of the telegraph apparatus and leads. Another fuse, 1 amp (R.C.), is provided for the protection of the motor. By means of a "Twinob" switch, this latter fuse is short-circuited as long as the switch is held down and automatically inserted in the motor circuits when the switch is released. Thus if the motor starts up normally and the switch is held down as specified for three seconds before being released, the fuse will not be blown by the starting current. Should the motor not have started up when the Twinob switch is released, or should the motor stop after running for a time, the current through the armature will blow

the fuse. The normal running current is not sufficient to blow the fuse. The circuit is shown in Fig. **1**.

Trials.—The circuit arrangements are shown, Fig. **8** and Fig. **9**, according as the line relay is a Standard " B " or a Standard " G " relay. In order to test the capabilities of the circuit a test was made between London and Leeds. The London (C.T.O.)-Leeds No. 1 circuit was taken over. This circuit is a 197 mile, U.G. 40-lb. metallic loop, having a D.C. resistance 8700 ohms. Normally, it works with " G " relay reception, line voltages of 120 volts at each end, local voltages of 80 volts supplied from secondary cells, and D.C. motor voltage of 110 volts. This

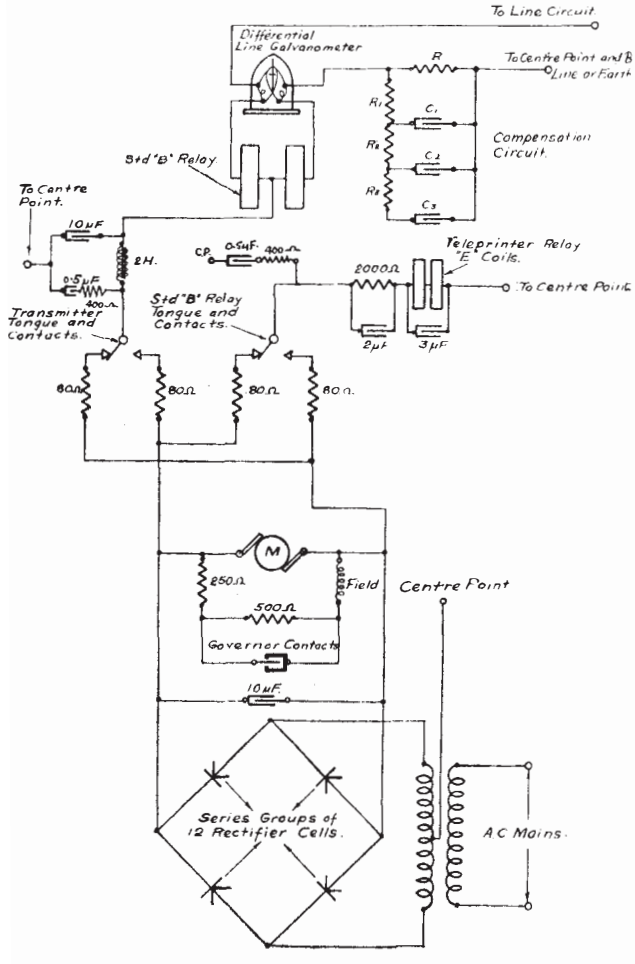


Fig. 8.—Complete Circuit with " B " Relay.

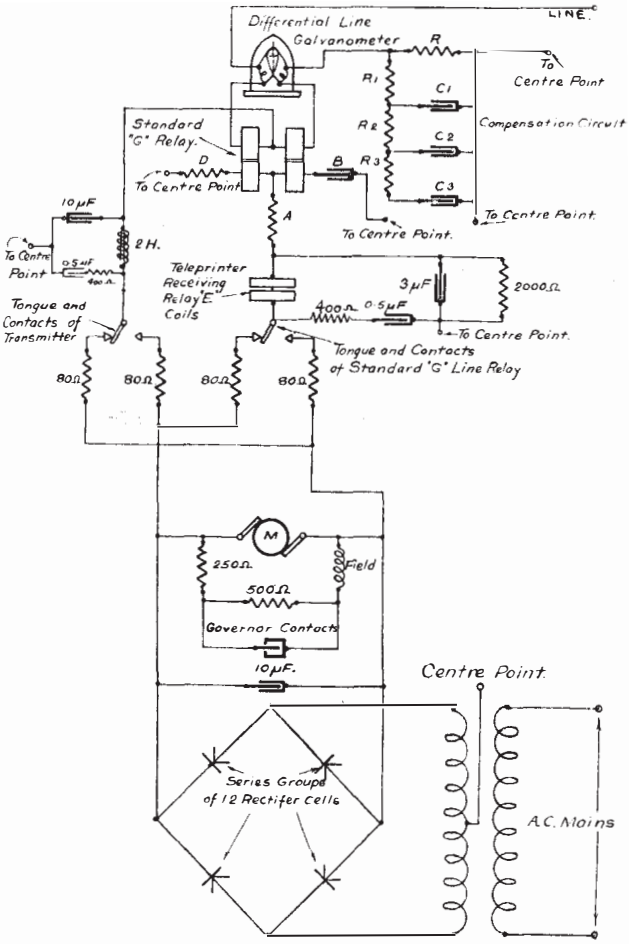


Fig. 9.—Complete Circuit with " G." Relay.

circuit was worked in full duplex traffic for a week with the rectifier supply sets at each end, the local and line voltages being 58 volts and the motor voltage double. The circuit functioned perfectly, the Leeds set being under " rack mounting " conditions with the Teleprinter remote from the remainder of the apparatus, and the line relay was not adjusted or cleaned during the whole week. This performance would appear to demonstrate the utility of such an arrangement. The power taken from the public mains supply, with all circuits connected, is approximately 110 watts only. Thus, not only is the first cost of such a unit small compared with normal battery installation, but the running costs are also negligible.

INTRODUCTION OF AUTOMATIC TELEPHONE SYSTEM AT BIRMINGHAM.

THE initial stage in the conversion of Birmingham's telephone system to automatic working was completed at 2 p.m. on the 7th March, 1931, when the first three exchanges were brought into use.

Particulars of the new exchanges are given below:—

Name of Exchange.	No. of Subscribers.	Multiple capacity. Initial.	Ultimate.
Northern ...	2,797	5,500	10,000
Victoria ...	1,775	3,100	7,200
Harborne ...	684	1,300	3,000

These exchanges are of the Director type, similar to those already in service in London and Manchester. The whole of the equipment, including that provided for the auto manual services located in the Midland Exchange building, was manufactured and installed by Messrs. The General Electric Co., Ltd.

The Birmingham telephone area, like that of Manchester, includes all exchanges within a radius of 7 miles from the centre, measured in this case from the Cathedral.

Fig. **1** shows the proposed locations of the 39 exchanges which are to serve this area.

Under the present programme the whole work of conversion has been projected over a period of about 10 years, but it is anticipated that at least 30 automatic exchanges will be brought into service during the next three years.

Call indicator positions have been installed by Messrs. The Automatic Telephone Manufacturing Co., Ltd., at certain manual exchanges in the area.

As the trunking arrangements for the Birmingham area and the general features of the equipment are almost identical in character with those described in an article by L. F. Morice, relating to the Manchester telephone system, published in the July, 1930, issue of this Journal, it is unnecessary to give further details on this occasion.

Fig. **2** is a photograph of the auto manual switchboard and Fig. **3** Tandem, First Selectors, Routiner and Relay Racks. These photographs were kindly supplied by Messrs. The General Electric Co., Ltd.

A.H.B.

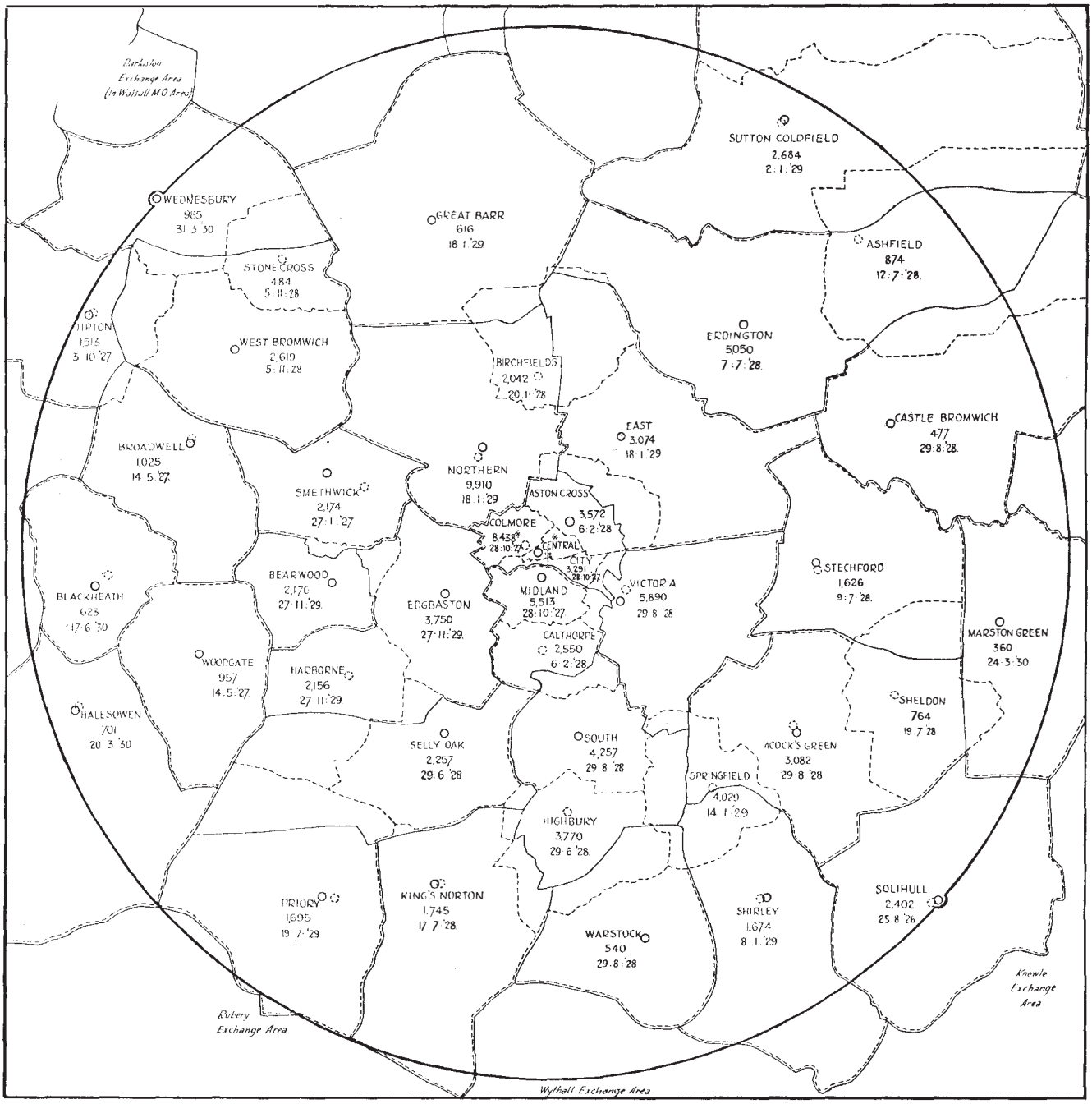


FIG. 1.—BIRMINGHAM TELEPHONE AREA.

FIG. 2.—AUTO MANUAL SWITCHBOARD.

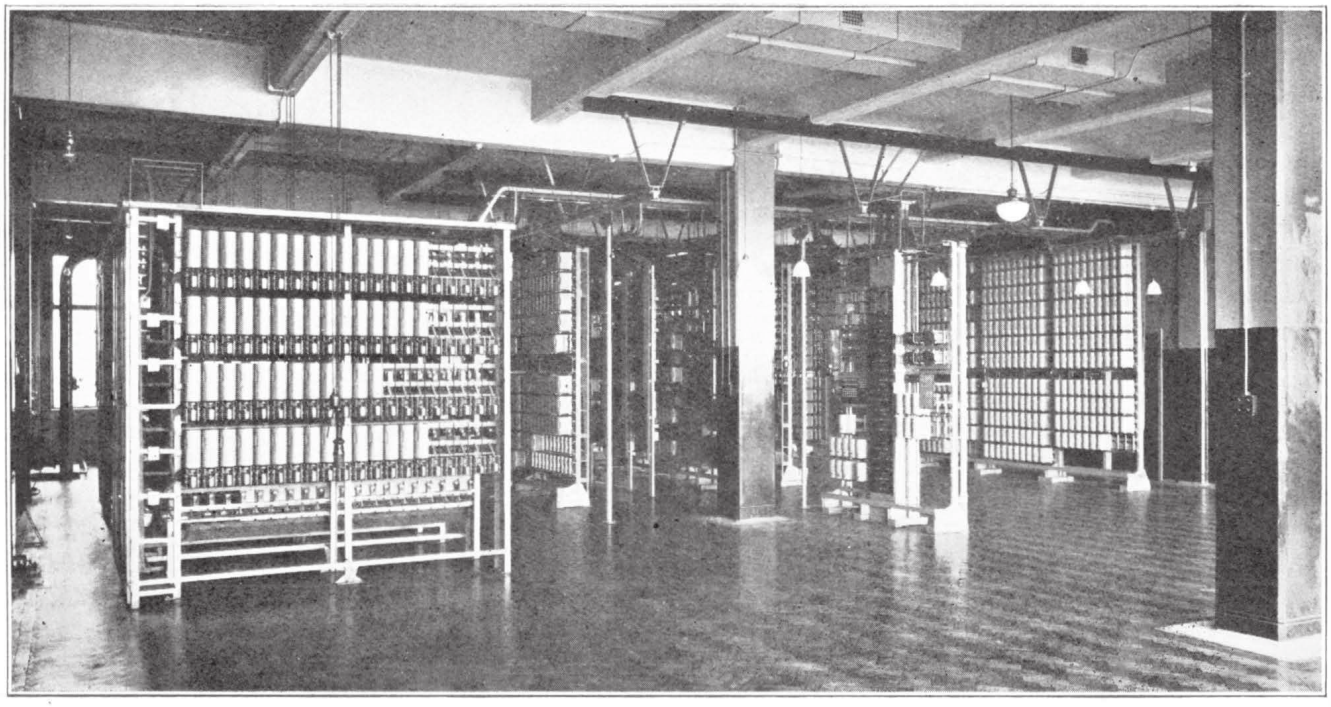


FIG. 3.—TANDEM. FIRST SELECTORS, ROUTINER AND RELAY RACKS.

ACORN EXCHANGE.

PROGRESSIVE INSTALLATION OF THE NEW STANDARD OPEN TYPE RACKS AND SHELVES.

B. HOUGHTON BROWN,

Engineering Division, Standard Telephones and Cables, Limited.

THIS article forms the second of the series dealing with the progressive installation of Acorn Exchange, and is written to report progress since the April issue of this Journal.

It will be recollected that the Exchange under review is being installed on a progressive sequence or piece-meal basis, consisting of three distinct operations:

(1) The shipping and erecting of the racks and frameworks, and the running of the cables.

(2) The shipping and erecting of the shelves.

(3) The shipping of, and placing in position of the apparatus.

The previous article concluded with a series of photographs showing the rack frameworks erected and the cables run in position, and we will now deal with the next stage covering the shipping, erecting and wiring of the shelves and miscellaneous apparatus, and will show by a further series of photographs how this has been carried out.

Working on the assumption that it is preferable from all points of view to carry out as much work in the Factory as possible, it will be realised that, unless special arrangements are made to reduce the amount of wiring to be done on site, the piece-meal method of installation would suffer in this respect from a distinct disadvantage, and even by making special provision considerably more wiring is thrown on the Installer than is the case where the racks are shipped fully equipped. To mitigate this advantage, arrangements have been made to assemble shelves in their respective groups with their associated supervisory relays and fuse panels on specially constructed tie bars, thus all wiring common to a particular group can be carried out by the Shops. This method of assembly has been used wherever the amount of inter-shelf wiring has merited its use; for example, the C.C.I. relay sets and coder-finder shelves and director shelves.

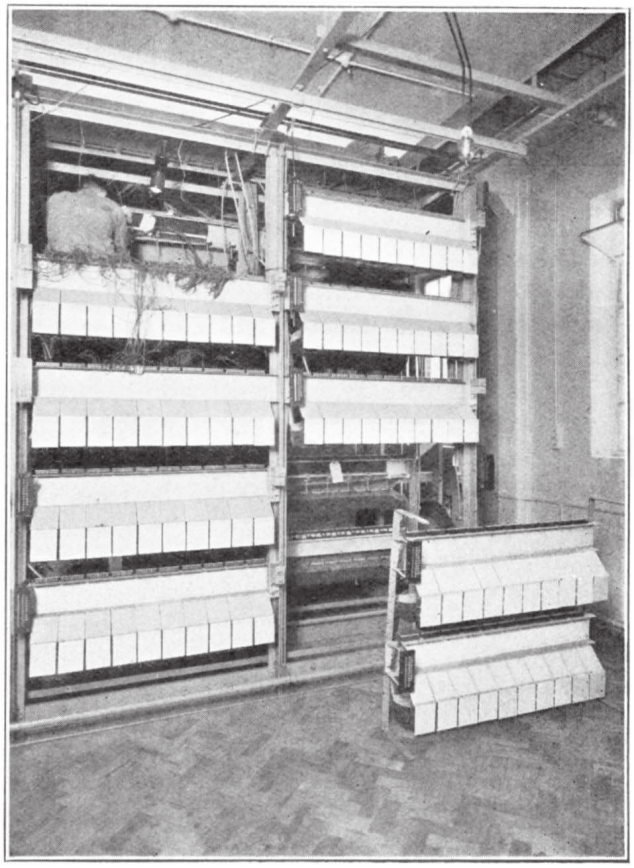


FIG. 11.

The method of assembling the shelf groups on the racks will be seen in Fig. 11, and its advantages will be appreciated in that no heavy lifting gear is necessary, the unit of two shelves being easily lifted and fixed in position by two men, and the tie bars removed. Having assembled the shelves on the rack, the Installer is left to connect up the necessary supervisory equipment, and for this purpose he is provided with a hand-made cable made up in the Shops.

In the case of the subscribers' uni-selectors,

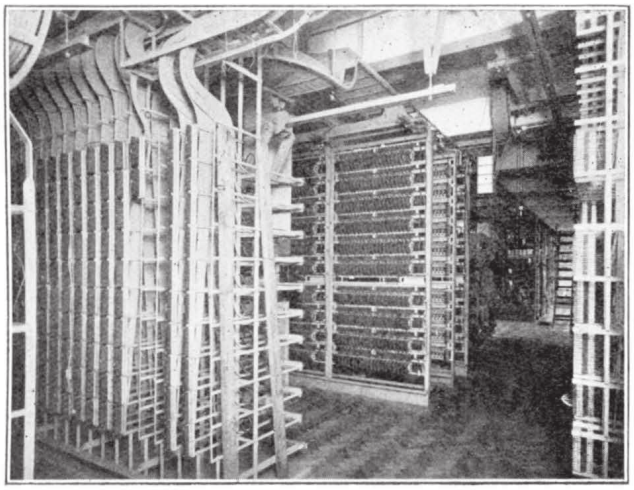


FIG. 12.—GENERAL VIEW.

the shelves are shipped fully wired and equipped, and are placed in position by the Installer, who connects up the battery and earth feeds and multiples the shelves together. This multipling is carried out with switchboard cable between terminal strips located at the end of each shelf,

FIG. 13.—WIRING GANGWAY, UNI-SELECTOR RACKS.

FIG. 14.—APPARATUS GANGWAY, UNI-SELECTOR RACKS.

and can be seen on the left-hand side of Fig. **13**.

The rear view of a fully equipped rack can be seen in the centre of Fig. **12**; this figure should be compared with Figs. **7** and **8** in the previous issue, and shows the general progress that has been made.

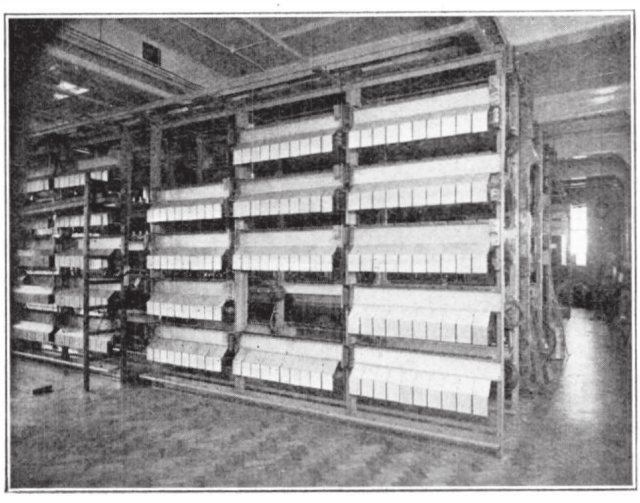


FIG. 15.—FINAL SELECTOR RACKS.

Fig. **13** shows the wiring gangway between two suites of uni-selector racks, and should be compared with Fig. **9**, also in the previous issue, when the advantage of having the cables run in prior to the arrival of the shelves will be apparent.

In the previous article it was stated that a new system of flood lighting was being considered, and this is clearly shown up in both Figs. **13** and **14**. The flood lights are controlled from either end of the gangway, the switch being mounted on the right-hand upright. For maintenance and inspection purposes, each wiring gangway is provided with a socket for a hand lamp. Fig. **14** shows an apparatus gangway between two suites of uni-selectors; here it will be noted that a different method of flood lighting has been made use of, owing to the presence of a travelling ladder in the gangway.

Fig. **15** should be compared with Figs. **5** and **6**, in the previous issue, and shows the final selector racks fully wired and equipped with shelves and bank multiples. The general appearance of the miscellaneous apparatus mounted down the right-hand side of the racks will be noted.

In concluding this, the second article dealing with the progressive installation of Acorn Exchange, it should be stated that the installation has so far proceeded according to programme, the piece-meal shipping having presented no serious difficulties, and having considerably added to the ease of service during installation and factory production.

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM.

TELEPHONES AND WIRE MILEAGES, THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 31ST MARCH, 1931.

No. of Telephones owned and maintained by the Post Office.	Overhead Wire Mileage.				Engineering District.	Underground Wire Mileage.			
	Telegraph.	Trunk.	Exchange.	Spare.		Telegraph.	Trunk.	Exchange.	Spare.
711,603	571	3,941	53,185	136	London	25,371	104,646	2,803,456	61,914
95,279	2,226	21,579	71,959	2,525	S. Eastern.	4,167	71,760	299,073	31,140
99,103	4,421	33,287	69,577	3,996	S. Western.	23,089	20,905	225,494	67,015
80,187	6,305	40,013	74,379	7,069	Eastern.	24,958	51,123	174,102	59,063
112,283	8,584	46,012	68,325	4,459	N. Mid.	35,225	74,722	296,280	92,812
99,346	4,779	32,163	84,106	4,063	S. Mid.	14,793	43,675	249,807	77,234
64,482	4,330	30,395	62,473	3,809	S. Wales.	7,973	34,852	147,336	64,231
123,570	8,016	27,469	59,056	4,504	N. Wales.	14,212	42,922	341,378	131,253
175,702	1,415	15,887	46,031	3,231	S. Lancs.	15,084	93,926	563,807	68,107
105,155	5,983	30,510	52,329	3,836	N. Eastern	16,028	54,362	288,605	66,945
71,091	3,795	24,002	42,316	3,121	N. Western.	8,371	38,155	191,789	41,858
54,687	2,412	16,154	28,848	3,187	Northern.	9,265	25,300	153,715	34,188
25,052	4,407	9,287	15,458	622	Ireland N.	138	3,162	59,436	2,406
75,744	4,658	28,157	44,497	1,472	Scotland E.	7,105	20,618	170,883	53,192
98,524	7,240	25,359	47,553	1,154	Scotland W.	11,989	31,508	250,404	32,775
1,991,808	69,142	384,215	820,092	47,184	Total	217,768	711,636	6,215,565	884,133
1,962,849	70,314	382,558	812,413	46,542	Figures as at 31 Dec., 1930	211,854	685,878	6,034,100	867,789

THE BYPATH AUTOMATIC TELEPHONE SYSTEM.

E. P. G. Wright and J. H. E. Baker, B.Sc., A.C.G.I.,
Standard Telephones and Cables, Ltd.

Introduction.

THE Bypath System is a universal automatic telephone system employing single motion switches (or uniselectors) of simple design as shown in Fig. 1. The development of this system has been carried out entirely in London and is the outcome of unremitting research work extending over a number of years, and resulting in the production of a system which, in the opinion of the authors, is superior to other Step-by-Step systems, and achieves in this class a standard of efficiency hitherto unattained.

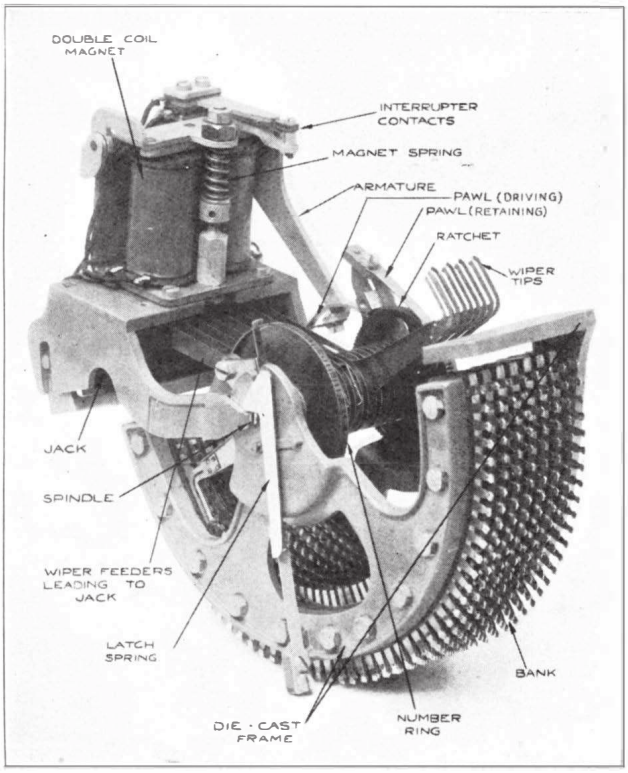


Fig. 1.—Single Motion Switch.

The term "Bypath" is descriptive of the operation of the system in that the circuits fall into two main categories conveniently known as paths and bypaths. The paths constitute the speaking connections which are engaged throughout a conversation, the bypaths being engaged only for a short period during the setting up of a call.

The bypaths control the positioning of the paths, and provide a temporary connection to the next switching stage until the connection *via* the path is completed. When the connection is established the bypaths are free for other calls, thus reducing the number of special relays associated with the apparatus individual to each call, and permitting the use of simple non-homing selectors in the paths.

The system caters for exchange capacities from a two digit unattended exchange to a 10,000 line exchange, which can exist as isolated exchanges or as units in a large metropolitan network, with or without exchange translation.

The system is designed to inter-work with the present Step-by-Step system or with any other system employing forward loop impulsing; a bypath exchange can therefore be introduced into areas at present employing such systems without modification to the existing exchanges.

Note:—The technical nomenclature used throughout this article is that defined in B.E.S.A. Publication No. 204—1930.

The main features of this system are:—

1. *Flexibility of grouping.*—Each switching stage has either 100 or 200 outlets, and the number of groups into which these outlets are divided, and the number of outlets in each group, are limited only by the total number of outlets.

2. *The use of a temporary bypath to the next switching stage.*—This arrangement greatly simplifies the conversational circuits and makes it possible for the path selectors to be non-homing without affecting the minimum allowable interdigital period.

3. *The use of common controlling circuits for positioning the conversational selectors.*—These circuits contain the impulsing relays and the slow and fast operating relays, thus reducing

the number of special relays required in an exchange. The ratio of bypaths to paths is about 1 to 10 for average traffic requirements, but, of course, is based upon trunking calculations.

4. *Circuit design.*—In designing the circuits, considerable attention has been given towards simplifying demands on relay design, and towards eliminating to a great extent the need for critical adjustments and timing requirements. A minimum contact pressure of 20 grammes has been adopted throughout.

5. *One type of selector.*—The use of only one type of selector is of special value for manufacture, maintenance and maintenance education. This selector has been especially designed for the system and has 6, 8 or 10 wipers arranged to give 51 or 102 outlets as required. An important feature of the new selector is the facility provided for jacking-in the brush carriage. This appreciably simplifies maintenance and allows for interchangeability.

6. *Translation.*—When translation is required, the registers and translators are used for setting up a call only when the call is to be routed by way of a tandem exchange or, in the case of the registers, when the call is to terminate at a call indicator exchange. This arrangement involves a considerably smaller number of registers than would be required if they were brought into use on every call.

7. *Alternative Trunking.*—This feature provides a means by which, in the event of all direct junctions between the two exchanges being busy, calls can be routed automatically through a tandem exchange. The advantage of this is that the number of inter-exchange junctions can be reduced by about 20% without materially affecting the number of junctions to tandem.

History.

The enormous amount of preliminary design work necessitated in the development of a new system is not generally realised, and it would be interesting briefly to run over some of the earlier arrangements which ultimately led to the bypath system and to show why each was abandoned.

The value of common controlling circuits and of the flexibility of the outlet groups on the bank of a single motion selector was apparent, and several schemes were worked out in detail showing how these principles could be applied to a typical exchange in the London area and to typical exchanges in the provinces, both with and without satellites. These schemes proved sufficiently economical and attractive to justify extensive further development.

The use of registers and revertive impulsing in conjunction with single motion selectors and common control circuits was investigated, but while results proved very satisfactory, the circuits did not readily interwork with existing Step-by-Step exchanges, and for this reason the method was abandoned.

It was felt that it might be advantageous to introduce common control working without materially departing from the principles at present employed in London and the Provinces and a scheme using two motion selectors with common control circuits at each switching stage was worked out in detail. This scheme was further developed to show how certain outlets on one or more levels could be used to increase the size of the trunk group of other levels, in order to give a higher trunking efficiency. This proved, however, to be cumbersome and the results were not encouraging.

The chief difficulty of a system using single motion switches without registers is in positioning the switches in the interdigital period. In the earlier schemes this was done by using comparatively complicated switches in the conversational circuits, which had to return home after every call and which had to be capable of testing two outlets at a time.

This latter requirement necessitated an additional switching relay in the conversational circuit and these schemes were not adopted since a system was subsequently evolved which enabled the common controlling circuit to establish a temporary connexion to the common controlling circuit of the next switching stage. Having thus established a bypath, the great majority (about 90%) of the complications referred to above are thus avoided and the selector in the conversational circuit moves in its own time to the position marked by the selector in the bypath.

Before the present system was decided upon several schemes employing this feature were developed, differing chiefly in the method of positioning the bypath switch in response to the

dial, and in the method of associating the conversational circuit with the bypath during the setting up of the call.

The Main Features.

Application.—The system is designed for Step-by-Step areas and is suitable for equipments of all sizes from a two digit isolated equipment to a 10,000 line exchange in a large multi-exchange area such as London.

The system interworks without any change with Step-by-Step systems or with any other systems responding to loop impulses.

Interworking with manual systems is catered for either by means of the well-known keysending method or by direct voice frequency signalling from the manual exchange. Both call indicator and call announcer methods for handling auto-manual calls have also been worked out.

Service.—The service to a subscriber is equal to that now afforded by Post Office automatic exchanges, and in addition it has the following advantages:—

1. The system is substantially immune from double connections due to marginal battery testing when searching for idle outlets at all stages.
2. The relays which respond to the dial impulses and step the selectors do not have to supply the transmitter current.
3. Continuous ringing is given immediately a subscriber's line is seized. This is replaced a quarter of a second later by the normal interrupted ringing.

Flexibility of Grouping.—One of the most important features of the system is the use of single motion selectors. These selectors have 100 outlets which can be divided into groups as required. Most telephone systems employ selectors having a definite number of levels with a definite number of outlets per level. This means that unless special arrangements are made, no group can have more than this fixed number of outlets and that if a level is not used, its outlets are wasted. On the other hand, the number of groups is not necessarily limited to 10, for example, there may be 9 groups of direct junctions (4, 6, 6, 8, 6, 12, 4, 6, 6), one group to tandem (16) and one group to sub-tandem (26), making 100 outlets altogether, divided into 11 dissimilar groups.

The table below shows the number of circuits required to handle given traffics when preceded by standard two motion selectors or single motion selectors with their outlets grouped for optimum distribution of availability.

The traffic is assumed to consist of:—

34·3 TC on each of 4 levels.
17·15 TC ,, ,, ,, 2 ,,
Zero ,, ,, ,, 4 ,,

The table gives the figures both for non-graded and graded connections and for 100 and 200 outlet cases.

	100 Outlets.		200 Outlets.	
	Non-graded.	Graded.	Non. graded.	Graded.
Two-motion selector	500	402	360	300
Single-motion selector with flexible grouping ...	378	320	306	268
Percent Saving ...	24·4	20.4	15.0	10.7

The above economy is effected by allotting outlets to each level according to the traffic carried by it. The figures shown for the single-motion selector assume four outlets allotted to dead levels in each example.

Another advantage is that where 100 outlets are required initially, and possibly 200 outlets required ultimately, the extension can take the form of simply adding the second selector and distributing the outlets as required.

Translation.—A feature of the system is the manner in which translation is handled. The translators, which are common to the exchange, control the routing of all tandemed traffic. The remaining traffic, which forms the greater proportion, goes either to the local selectors or over inter-exchange junctions under the direct control of the dial. Each translator controls the routing of all calls going to nine exchanges. Thus the quantity of translators can be chosen to suit the number of exchanges in the area and can be varied as required.

The registers store the numerical digits and

are taken into use only on tandem and call indicator traffic. They send out the code digits under the control of the appropriate translator. In the event of all direct junctions to an exchange being engaged, calls to that exchange are routed *via* a tandem exchange.

The advantages of these arrangements are as follows:—

(*a*) It is necessary to provide only a fraction of the number of storage registers which would be required with the present Step-by-Step System, as for example in London.

(*b*) The number of inter-exchange junctions is considerably reduced without appreciable increase to the tandem junctions. In most areas there will be a large group of junctions from each exchange to a tandem centre to cater for the traffic to the more outlying exchanges. With the alternative trunking feature, congestion on the inter-exchange junctions does not result in lost or delayed calls, unless in addition, all the tandem outlets are busy. Consequently, the direct junctions, which are usually in small groups, can be calculated on a much higher probability of congestion, resulting in an average reduction of about 20% in the number of junctions. The overflow traffic, which will be very small and probably not occur simultaneously in each group, will hardly affect the number of tandem junctions since they are already in a large group.

(*c*) Following on (*b*) the provision of alternative trunking allows the equipment to meet sudden emergency traffic conditions without degrading the service. The elasticity of this arrangement takes care of unavoidable deviations from the traffic predicted by the operating administration in forecasting the equipment and allows a greater traffic growth to occur before action need be taken.

(*d*) Each translation appears only once in the exchange, thus reducing the possible sources of error, facilitating alterations and considerably minimising routining and maintenance work.

(*e*) Since the local and direct junction calls are set up under the direct control of the dial as opposed to the intervention of a register or director, the average time the subscriber has to wait from the moment of dialling the last digit to the moment of hearing ringing tone, is reduced by 4 seconds, which is a considerable advantage from the subscriber's point of view.

Traffic to Manual Exchange.—The registers which store the numerical digits are designed to re-transmit them either as decimal impulses or as coded call indicator pulses. This means that only one type of register is required for tandem calls and direct manual calls.

Maintenance.—A very great effort has been made to reduce the maintenance costs, and the main factors leading to the advantages claimed are as follows:—

(*a*) The presence of common circuits in which are located the testing, guarding, impulsing and marginal relays, not only considerably reduces the number of relays of this class, but makes it economically possible to provide relief relays on a fairly lavish scale, which has the effect of easing the relay design limits and broadening the operating limits of the more difficult relays.

(*b*) A minimum contact pressure of 20 grammes on all relay springs materially reduces trouble due to dirty contacts.

(*c*) Selector maintenance has been reduced to a minimum by virtue of the following:—

1. The banks and mechanisms are interchangeable, and the wipers having been centred on one bank require no further centring on other banks.
2. The mechanism can be jacked in and out in a few seconds without the use of any tools, and the thumb screw which fixes the mechanism to the bank always remains attached to the mechanism.

3. These features enable the mechanism to be taken away for maintenance purposes to any convenient working position where all the necessary tools can be available, and the best conditions of working can be provided.
4. All the adjustable parts are readily accessible.
5. There are no auxiliary spring sets.

(*d*) The relay panels can also be jacked in in and out, and the winding tags of the more important relays are taken out to jack points to facilitate current adjustment on the bench.

(*e*) The bypaths which form the hub of the system are mounted at about four feet from the ground on all bays.

(*f*) The provision of automatic routiners which test the correct make and break of every contact at all selecting stages makes it possible to check all the apparatus in a very short time for correct operation, and in the case of failure gives, by means of lamps, a direct indication of the probable cause of failure.

(*g*) The use of bypaths makes it possible to have separate relays for receiving the dial impulses during the setting up of a call and for battery supply purposes when the call has been set up. Since the properties for good transmission and good impulsing are conflicting, this segregation of duties enables the most efficient relay to be used in each case.

(*h*) In the event of a subscriber failing to dial after a predetermined time interval, the common apparatus is forcibly released and the subscriber's line is tied to a first path and a P.G. (permanent loop) alarm is given. If this condition persists for more than a predetermined time an exchange alarm is given.

(*i*) The release of the connection is under the control of the calling subscriber who, on hanging up, breaks down the connection as far as the penultimate stage; the remainder of the connection is under the control of the called subscriber, but this control is not effective unless the calling subscriber has already hung up. This arrangement prevents the called subscriber getting dial tone if he is late in hanging up. If the last subscriber fails to hang up after a reasonable length of time, the connection is forcibly broken down and the line is treated as a P.G. It will be seen, therefore, that all the maintenance work connected with switchhook conditions is concentrated at the first stage. This eliminates the tracing back of C.S.H. (Called subscriber held) faults.

(*j*) In order to ensure that no bypath is held for an undue length of time, a fault detector is provided which continuously tests each bypath in turn. If the bypath is free, it passes to the next, but if a bypath is busy, it remains there until it becomes free, giving an alarm if this does not occur within a predetermined time. This fault detector is in addition to individual time alarm arrangements, which are provided on each circuit.

(*k*) The only alarms in the exchange are given when a fuse blows, when a routiner finds a fault, when the fault detector is held up, or when a P.G. persists for more than a predetermined time.

Preselection.—First and second line finders are used in such a manner as to give maximum availability between the first stage circuits and the subscriber's lines.

The bypaths search first for the 100 line group calling and then cause first line finders to search for the calling line within that group. The bypaths are arranged in pairs, and of each pair one is brought into operation at the initiation of every call, but only two first line finders search for the calling line within the 100 line group.

Junctions.—The Bypath System claims two advantages in relation to junctions. Firstly, by the use of alternative trunking the number of inter-exchange junctions is materially reduced, and, secondly, by the use of separate relays for impulsing and transmission it is possible to dial

with more difficult line conditions and impulse repetition is made easier.

Incoming junctions are terminated on the banks of finders which are so arranged as to ensure even distribution of the finders around the arc. This gives an efficient method of introducing the bypath at the incoming stage without interfering with the interdigital time.

Traffic Recording.—The System lends itself very readily to the use of a traffic recorder. On account of the ease with which selector mechanisms can be jacked in and out, it is a simple matter to re-group the selectors to obtain the highest traffic carrying efficiency.

The outgoing tandemed traffic is measured at the translators, where means are provided for recording the total traffic to each exchange individually. This is effected by plugging a meter circuit into the start circuit jack for the particular exchange required, and gives a very ready method of checking the traffic without any wiring or strapping being necessary.

Metering.—The system caters for excess fee or zone metering. When the called subscriber answers, the calling subscriber's meter is operated a number of times according to the fee to be charged. The record of the fee to be charged is signalled to the outgoing relay set at the originating exchange from the register.

Equipment.—The equipment is mounted on vertical bays, 11 ft. 6 ins. high and about 2 ft. wide. Each bay carries either two or four bypaths (depending on the switching stage) and the paths normally associated with the bypaths. The relays, supervisory keys, and test jacks are mounted at approximately four feet from the ground on each bay, the selectors being mounted above and below them. The relays are mounted on jack-in panels and are provided with transparent covers so that the condition of the relays can be observed without removing the covers. Ordinary switchboard jacks are used for test jacks, and their robust construction avoids maintenance troubles.

Final Selectors.—The same group of final bypaths is used for regular and P.B.X. working and for the test and trunk trains, thus eliminating small groups for special services. Special finals are not required for P.B.X. working, since the paths are identical, and the small amount of equipment which is special to P.B.X. lines is provided in all the bypaths.

Facilities are provided for intermingling regular subscribers in P.B.X. groups and for extending P.B.X. groups over the home position. These facilities enable P.B.X. group extensions to be made and regular subscribers to be converted into P.B.X. subscribers without changing the subscriber's number.

Ringing.—Continuous ringing is applied to the terminals of the wanted line immediately after it is seized, and after about 200 milliseconds is replaced by the usual interrupted ringing. This feature is particularly useful in the case of P.B.X. lines since it prevents P.B.X. operator seizing a line to the exchange after it has been taken by a final selector due to the seizures coinciding in the silent period of the ringing. It also decreases the operating time, thereby improving the service from the subscriber's point of view.

Satellites.—The Bypath System is easily adaptable to satellite working and depending on the type of the area and the nature of the traffic, either a discriminating first stage is used with the discriminating apparatus located in the bypath, or for large satellites running into several thousand lines, a register with or without translators is used. Where registers are provided, only a few are required, since they are brought into operation only when they are required for the particular class of call. In this way the number of junctions between the satellites and the main exchange is materially reduced. The same path selector is used for both the local and junction traffic and facilities are provided for direct working to neighbouring satellites.

Bypath Change-over Keys.—The bypaths are arranged in pairs, each bypath normally serving a group of paths, but in the event of a bypath being cut out of service the paths normally associated with it can be made accessible from the partner bypath by means of a change-over key. With this key thrown, the remaining bypath will serve both groups of paths.

Automatic Routiners.—Automatic routiners are provided at every switching stage where the number of circuits is such as to justify their presence. These routiners test the correct making and breaking of every contact in the bypaths and paths and take, on the average, about 75 seconds to routine a bypath and its associated

group of paths.

Facilities are also provided for continuously routining one particular circuit where an intermittent fault is suspected. In the event of a fault being found, its nature is indicated on a lamp field so that it can be readily tracked down.

The routiner is also used as the fault detector as has already been described.

Battery Supply.—The current consumption of a bypath exchange is approximately 10% to 20% less than that of an equivalent Step-by-Step exchange. A nominal voltage of 50 is used with a permissible variation from 46 to 52 volts. Separate battery feeds are provided for talking and operating purposes.

Location of the Feed.—In the Bypath System the transmission feed is located in the penultimate path and in the outgoing relay sets. This arrangement results in distinct economies compared with the usual practice of having the feed in the final selector, since the latter selectors which serve groups of 100 or 200 lines are more numerous than the penultimates which serve groups of 1,000 lines.

Discrimination is made in the relay sets and in the penultimate stages as to whether the call has come from an operator. In this case the operator's cord circuit already has a feed, and consequently a second feed is unnecessary and is accordingly replaced by a through metallic pair. One advantage of this arrangement is that busy flash need not be repeated through the relay set, the elimination of which facility considerably simplifies the circuit. A second advantage is that the transmission is improved.

Release.—When a call is broken down at the end of a conversation, the path selectors do not move, the wipers remaining disconnected on the contacts until the path is taken into use again for another call. This reduces the wear on the path selectors by approximately 50%, and maintenance is facilitated in that the selector remains on the outlet after the conversation has ceased.

Spark Quenches.—Only one path selector of a group of paths served by the same bypath can move at a time, since no movement can take place unless it is controlled by the bypath. Advantage has been taken of this fact and only one spark quench is provided for all the path selectors served by one bypath; this is located in the bypath and introduced when required. The method of introduction is such that with any combination of dirty contacts, it is not possible to drive the selector without the spark quench being connected correctly.

Testing for free Outlets.—A free outlet is indicated by having battery potential, and the testing circuits are so arranged that provided the apparatus is in adjustment it is impossible for two circuits to seize the same outlet. This makes double connections virtually impossible and has the additional advantage that a circuit cannot be seized if the fuse is blown.

The selectors drive at a speed of 60 steps per second (minimum) and the outlets are tested two at a time. This high speed of testing enables large groups to be hunted over without interfering with the interdigital period.

Traffic between the Auto-Manual Board and the Automatic Equipment.—A trunk indicator circuit is used for this purpose. The operator depresses the order wire button associated with the group of trunks required; the jack to be used is selected automatically, and is indicated by a lamp. This method does away with the click test for small groups, and the group click test or visual engaged signals for the large groups. The latter is not satisfactory on account of the glare and the battery drain, and the former is inconvenient for large groups.

General Description.

In principle the line finding arrangements are built up in 5,000 line units, comprising 50 groups of 100 lines. First and second line finders are used and in a 5,000 line unit every first stage path has access to every line.

Each selecting stage is divided up into paths and bypaths. The paths convey the conversational current and are held throughout the call. The bypaths are taken into use for positioning the path selectors and are released immediately the paths are ready to take over. The progress of a call is indicated in Fig. **2**, which shows how the bypath circuits are released stage by stage as the connection is established.

On the initiation of a call, half of the available first bypaths associated with the 5,000 line unit are seized momentarily. The bypath group finders hunt for the group of 100 lines in which the call originated. When two such bypaths have found the group, the remaining bypaths

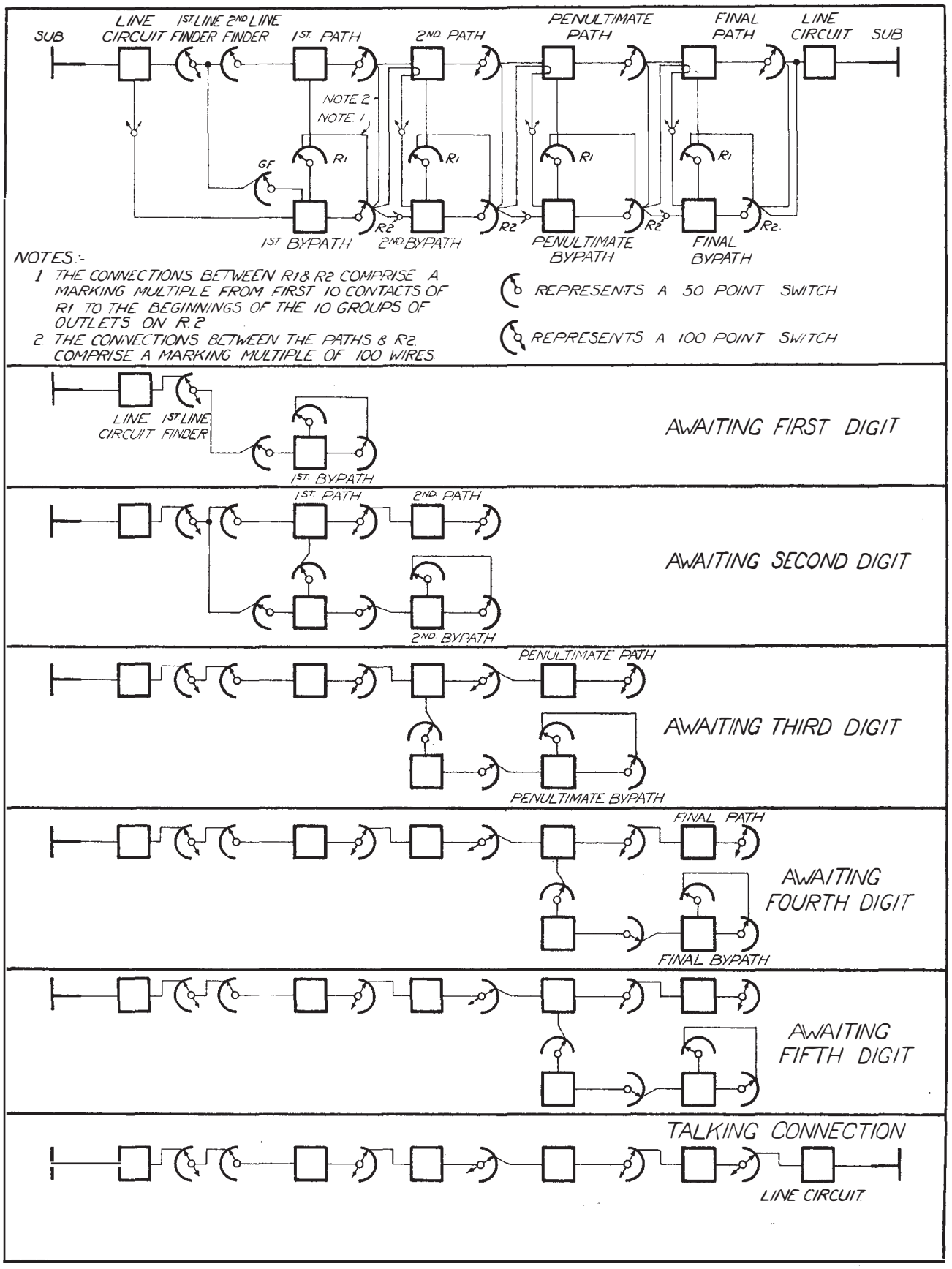


FIG. 2 SHOWS HOW BYPATHS ARE RELEASED STAGE BY STAGE.

come to rest. A test is made to ensure that access is available between the paths under the control of that bypath and the calling subscriber. Each of the two successful bypaths causes a first line finder in the correct 100 line group to hunt for the calling line. Two first line finders, therefore, hunt for each call.

When one first line finder has found the calling line, the other is brought to rest and its bypath released. The line is now extended over the first line finder and the group finder to an impulsing relay in the first bypath and dial tone is given to the calling subscriber.

Apart from the group finder, the bypath has two other selectors known as R1 and R2. R1 responds to the dial impulses and pilots R2 to the required group. R2 searches in that group for an idle second stage path whose bypath is also free and R1 hunts for an idle first stage path. When R2 has found a free second stage path, the positive and negative lines are switched through direct to the second stage bypath, while the test lead holds the path busy.

When R1 has seized its path, the second line finder is rotated to the position marked by the group finder in the bypath and the selector is rotated to the position marked by R2. During this period a temporary path has been established to convey the next series of dial impulses over the banks of the first finder, the group finder and R2, to the impulsing relay in the second stage bypath.

Like the first bypath, the second stage bypath has an R1 and an R2 selector. R1 responds to the second digit, piloting R2 to the correct group. R2 then searches for an idle outlet to the penultimate stage, while R1 hunts for the path as marked for the call by the first stage path, in order to provide paths of access between the bypath and the path to enable the positioning of the path to be controlled.

When communication has thus been established between the path and the bypath of the second stage, the first stage bypath is dropped and is available for another call.

The call proceeds in this manner from stage to stage, but the penultimate bypath remains in circuit until the wanted line is tested, in order to signal to the penultimate path whether the line is free or busy; immediately this signal is conveyed, the penultimate and final bypaths are released and the connection is left established over the paths.

The connection is held from the penultimate path, which provides the talking current to both subscribers.

At the moment the wanted line is seized, continuous ringing is transmitted for about 200 milliseconds, followed by the usual interrupted ringing, which is tripped when the called subscriber answers.

The release of the connection is normally under the control of the calling subscriber, but should the call be held for more than a predetermined period after the called subscriber has cleared, the whole connection is forcibly released, the calling line appearing as a permanent loop. Conversely, should the calling subscriber clear but the called subscriber fail to clear, the train will be released as far as the penultimate path, which path, together with the final path, is held under the control of the called subscriber, in order to prevent the line finders coming into operation unnecessarily. If the called subscriber continues to hold on for more than a predetermined period, the remainder of the train is forcibly released and the called subscriber is treated as a permanent loop.

In the event of the wanted line being busy, or the bypaths failing to find an idle outlet at any stage, busy tone is sent back to the calling subscriber.

If the system is applied to a multi-exchange area, outgoing relay sets and special incoming stage circuits are used.

The outgoing relay set is reached from the R2 switch of the 1st or 2nd bypath, repeats the impulses over the junction and holds the preceding stages operated. When the preceding path selector is positioned, a relay is operated in the relay set which causes the release of the bypath. The path circuits and the relay set remain in circuit during the conversation, the latter controlling supervision and metering.

The incoming stage circuit differs from an intermediate stage circuit in that the bypath cannot be tested directly over the junction. The junctions are terminated, therefore, on line and cut-off relays and the incoming paths and bypaths have finders which pick up the calling junction, special steps being taken to ensure rapid finding.

COMMON CONTROL SYSTEM.

R. TAYLOR and C. E. BEALE,
Engineering Department, Automatic Telephone Manufacturing Company, Limited.

AS a preliminary to a brief description of the Common Control System, it would appear desirable to draw attention to certain features of the British Post Office Step-by-Step System employing uni-selectors (rotary line switches), in order to emphasise the two basic principles that have been incorporated in the new system to secure important economic advantages.

In the Department's present standard system, each switching operation is effected under the control of a number of relays, which are definitely associated with individual switches. The number of relays provided depends upon the particular switching stage, and upon the functions to be performed. Thus, 10/10 group selectors have five relays, whilst regular final selectors have either eight or nine relays. It will be appreciated that, whilst each of the relays of group selectors rapidly functions in a definite sequence to establish connections, only one relay —*i.e.*, the wiper switching relay—remains held for the duration of the call. Thus for something like 99% of the holding time of the switch, four of the five relays perform no useful function. Similarly, on regular final selectors, only four of the eight or nine relays are held for the full duration of the call.

There are thus a number of relays that perform what may be termed transitory functions, and in the Common Control System these transitory functions are performed by detached groups of relays, each group being arranged to control a number of switches. To the switches themselves are fitted only the relays that are required for the full duration of the call, plus one relay that serves to link up with the common control group during the setting up of the call. The total number of relays is therefore considerably less than in the present standard system, and this, of course, effects important economies, both in first cost of the apparatus, and also in mounting space. For example, whilst a 10′ 6″ rack mounts 70—10/10 group selectors, having a total of 350 relays, the same rack mounts 80—10/10 common controlled selectors, together with the common control relay groups, making a total of only 220 relays. There is thus an average of only 2.75 relays per switch, as against 5 per switch, whilst 11.4% more can be mounted in the same space.

This principle of common control is by no means new, having been patented so long ago as 1913, but it is only recently that, due to the steady improvements in manufacturing methods and to the increasing use of auto-routiners, it was felt that advantage could be taken of the economies it makes possible.

Consideration will now be given to the line finder principle, which has already been extensively adopted in America and Canada by the Bell Telephone Companies and by the Canadian Bell Telephone Company respectively. 20,000 lines of line finder equipment have recently been installed in Victoria, B.C., for the British Columbia Telephone Co. and Director line finder equipment is being installed at the present time in the Johannesburg Area for the South African Post Office.

A total of approximately 700,000 lines of Strowger line finder equipment is giving service in large exchanges in various parts of the world.

Unlike the present system, in which each subscriber's line is provided with an individual uni-selector and pair of line and cut-off relays, the Common Control System employs small groups of two-motion switches operating in the reverse direction and functioning as line finders, each group serving 200 subscribers lines. Line finder switches are provided at the rate of from 12 to 30 per 200 subscribers, depending upon traffic values.

In regard therefore to the method of operation on originating calls, the two systems are fundamentally different. On the present system, the subscriber's uni-selector hunts to extend the caller to a trunking switch, whereas on the line finder system a preselected finder switch hunts to find the calling line for the purpose of extending it to a trunking switch. Hence, the line finder system is much more economical in regard

to the apparatus employed to seize a switch for the first switching stage, due to the substitution of relatively few two-motion finder switches in place of individual uni-selectors.

Attention is drawn to the fact that, excepting the manner in which calling parties are extended to the first rank of switches, both the present and line finder equipments employ identically the same types of switches for subsequent switching operations.

Now the Common Control System combines the substantial economic advantage of the line finder system with that of the common control principle, the latter being incorporated in every switching stage, commencing with the seizure of a trunking switch in the first rank. The total resulting economy is thus substantial in comparison with the present standard system, amounting to the following approximate reductions in exchanges of average sizes.

	% Reductions.
First cost of automatic apparatus	20%
Mounting space	30%
Volume of apparatus	29%

It follows that these reductions will effect substantial economies in building costs also.

Furthermore, in view of the fact that the switching mechanisms employed in the Common Control System are practically all of the two-motion selector type, maintenance is still further simplified, since there is only one main type of switching component to maintain instead of two as on the present standard system.

Circuit arrangements of the Common Control System have been completed for both Non-Director and Director areas, including the well-known principle of satellite working, employing discriminating selector repeaters. All the circuits conform strictly to the Department's standard circuit principles, including "make drive," priority switching in 10/20 group selectors, fast wiper switching relay in final selectors, etc. Further, since the more important relays, (A, B and C) are in common groups, they are easier to maintain and, as they are required to function only in the setting up of calls, it is thus permissible to design them for maximum impulsing efficiency, instead of their being required to combine the dual functions of battery feed and impulsing, as in the individually controlled system.

Fig. **1** shows a 10/10 group selector of the existing type, having five relays arranged for individual control, whilst Fig. **2** shows the 10/10 group selector having only two relays and arranged for common control.

Fig. **3** shows the general arrangement of the Common Control System for Non-Director areas. In this particular arrangement each subscriber's line is provided with a single relay only, which combines the functions of separate line and cut-off relays. This relay functions satisfactorily on loops up to 1200 ohms. As previously mentioned, subscribers' lines are arranged in groups of 200 lines, which are served by groups of 200-point finder switches of the two-motion selector type.

When a calling party lifts the receiver to make a call, the operation of the line relay operates a start relay in the distributor. The operation of the line relay also "marks" the calling subscriber's line on the finder switches, whilst the operation of the start relay immediately causes a preselected finder switch to hunt both vertically and horizontally until the calling line is found. Thereupon, the calling line is switched through to a first selector and common control relay set. The calling subscriber's line relay is then caused to perform the cut-off function, to clear the line and release the distributor, which then preselects another finder switch in readiness to deal with the next call.

This sequence of operations is normally accomplished by the time the calling subscriber has placed his receiver to his ear to listen for dialling tone.

As each digit is dialled, the successive common control relay sets are released, leaving the connection held by a minimum number of relays, as shown in Fig. **3**.

Circuit Operation of 10/10 Group Controlled 2nd Group Selector. See Fig. **4**. As stated above, 200-point selectors would normally be employed, but to facilitate description the circuit of a 100-point, or 10/10 selector, is given.

When seized for the purpose of establishing a call, relay K in the switch and relay A in the common control relay set operate in series. Operated contacts A1 close the circuit of relay B, which operates to apply earth at operated

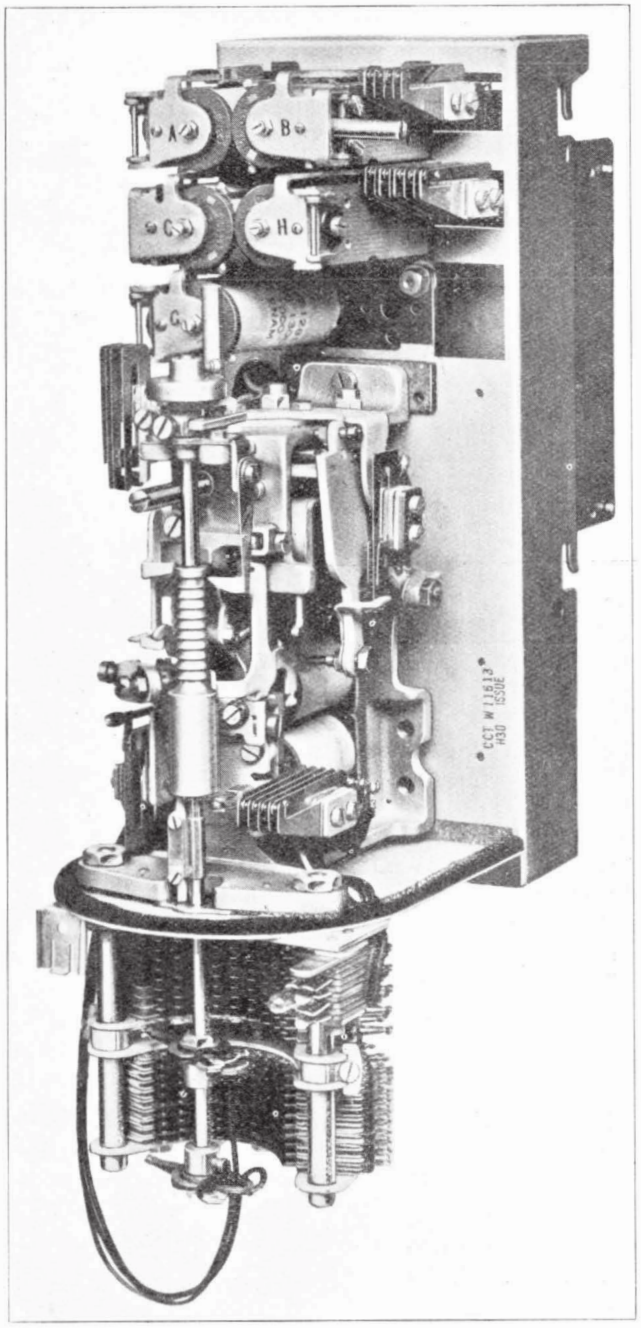


FIG. 1.—10 to GROUP SELECTOR AS AT PRESENT USED.

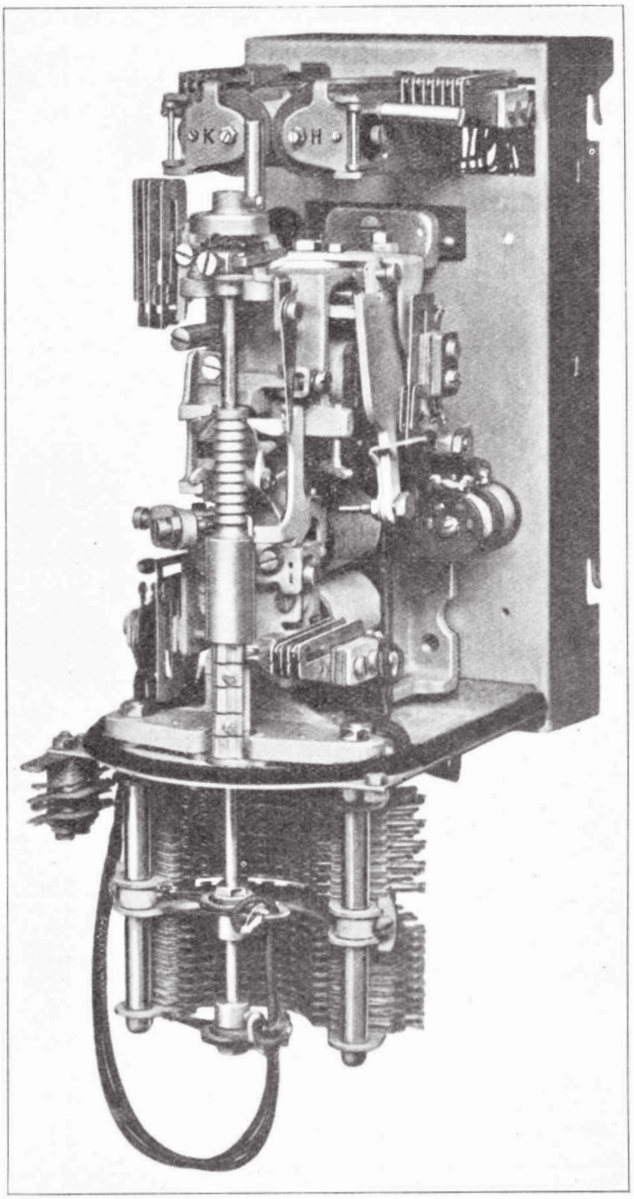


FIG. 2.—10 to GROUP SELECTOR FOR COMMON CONTROL.

contacts B2 to the P wire to hold the preceding switches. Operated contacts B2 also complete a locking circuit for relay K, whilst operated contacts B3 prepare the vertical magnet circuit. Operated contacts B1 also earth the P wire, to provide an overlap earth on switching through. Relay A responds to the dialled impulses and causes the shaft to be stepped over the circuit-pulsing contacts A1, operated contacts B3, normal contacts BB2, 4 ohms winding of relay C, rotary normal springs NR and operated contacts K3. Relay C remains steadily operated during the vertical action and, due to being slugged, releases in about 100 milli-seconds after the shaft has been raised to the level dialled.

The rotary magnet circuit is then completed *via* operated off-normal springs, N, operated contacts K4, normal contacts G2 "y," restored contacts C3 and operated contacts B2. The wipers are therefore cut-in to the first set of contacts and, if these are engaged, relay G operates *via* the operated rotary interrupter contacts, R,

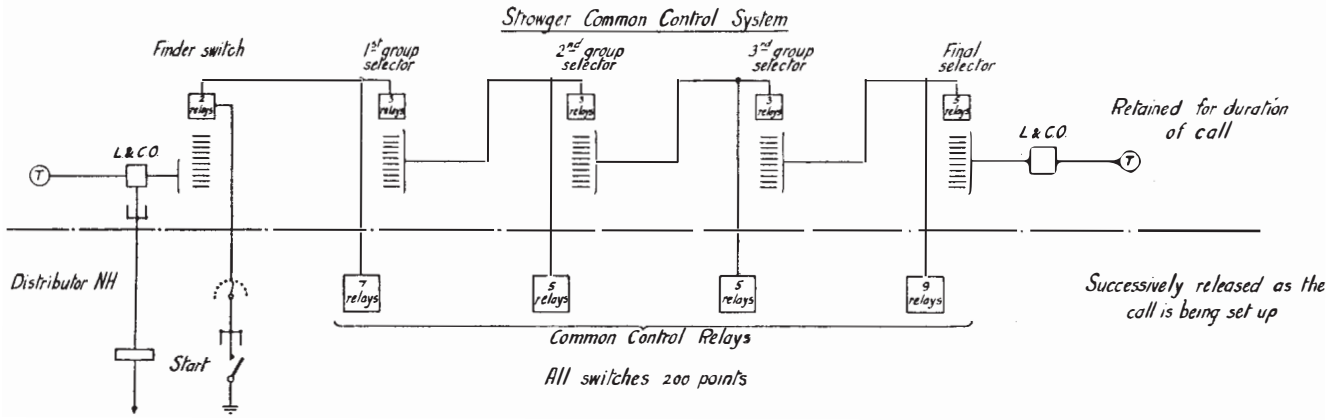


FIG. 3.—FOR NON-DIRECTOR AREAS.

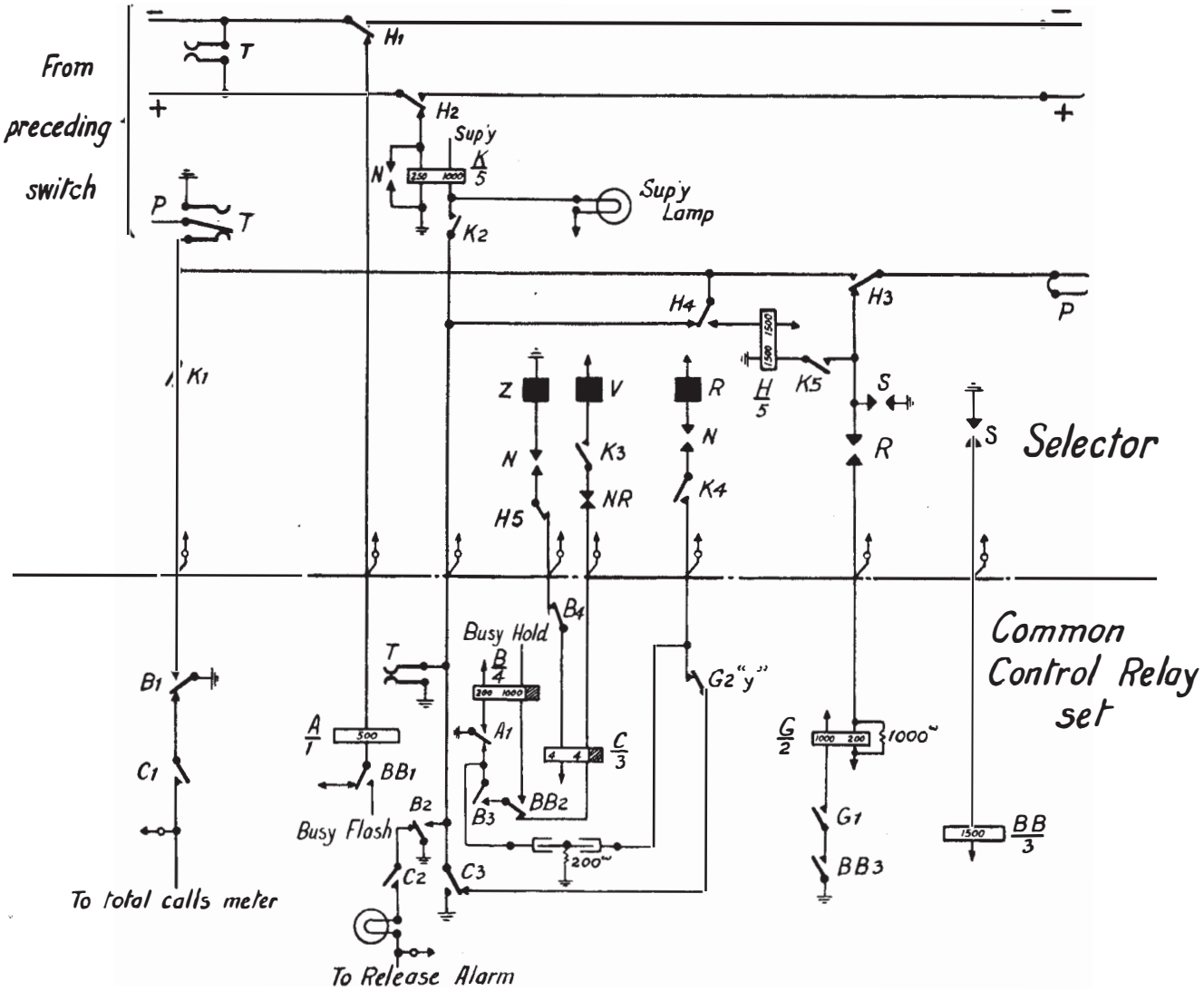


FIG. 4.

normal contacts H_3, and positive on the P wiper. Relay G disconnects the rotary magnet circuit at operated contacts G2 "*y*." The rotary armature therefore releases and disconnects the rotary interrupter contacts, R, thus releasing relay G. This cycle of operations continues until the wipers reach a disengaged set of contacts, whereupon relay H operates in series with relay G, which, however, remains normal, due to the high resistance of relay H. The operation of relay H switches the line through to a selector in the next rank, *via* operated contacts H_1, H_2 and H_3. Relay A in the common control set is then disconnected and therefore releases, being closely followed by the release of relays B and K.

The switch is held by relay H to the P wire, whilst the common control relay set is now free for further use.

In the event of all outlets being engaged, the wipers would be rotated to the 11th step, whereupon the cam springs make contact to operate relay BB and connect earth to the private wiper for overflow metering. The operation of relay BB holds relay G to prevent further rotary motion, connects busy hold to relay B and connects busy tone and flash through relay A to the calling party.

One feature of the Common Control System that contributes to the high economy of the system as a whole is that of partial secondary trunking, which is employed in connection with the line finders, and may be explained as follows:—Assuming that the originating traffic per subscriber is 0.05 T.U., then the total traffic for a group of 200 subscribers would be 10 T.U., which, with a grade of service of 1 in 500, would require 20 line finders. If 10 T.U. are offered to 20 line finders in a definite order, it can be shown that the first 12 line finders will carry 8.8 T.U. or 88% of the total traffic, whilst the remaining 8 switches will only carry 1.2 T.U. or 12% of the traffic. Under these conditions the average occupancy of the first 12 line finders is 0.733 T.U., as against an average of only 0.150 T.U. for the last 8 switches. If now a group selector be definitely associated with all the 20 line finders, the average occupancy of the first 12 selectors would be satisfactory, whilst that of the last 8 selectors would be extremely low. Therefore, in order to increase the average occupancy of the selectors associated with the last 8 line finders in each 200-lines group, partial secondary finder equipment is employed, and consists of 8 groups of secondary finders of the uni-selector type. One line finder from each 200-line group is connected to each secondary finder group and full availability conditions thus obtain with regard to the selectors associated with the secondary finders.

It should be noted that the bulk of the busy hour traffic is carried by those line finders that are directly associated with selectors, and that the partial secondary equipment is only called upon during the peak periods of the busy hour. The circuit arrangements are such that, whilst the finder switches are not tested in a definite order, a call cannot engage a finder in the secondary group unless all the primary finders are engaged.

Under these conditions, the traffic overflowing from the direct group into the indirect group will be the same as if the line finders were tested in a definite order up to the dividing point between two groups.

In conclusion, it may be remarked that the

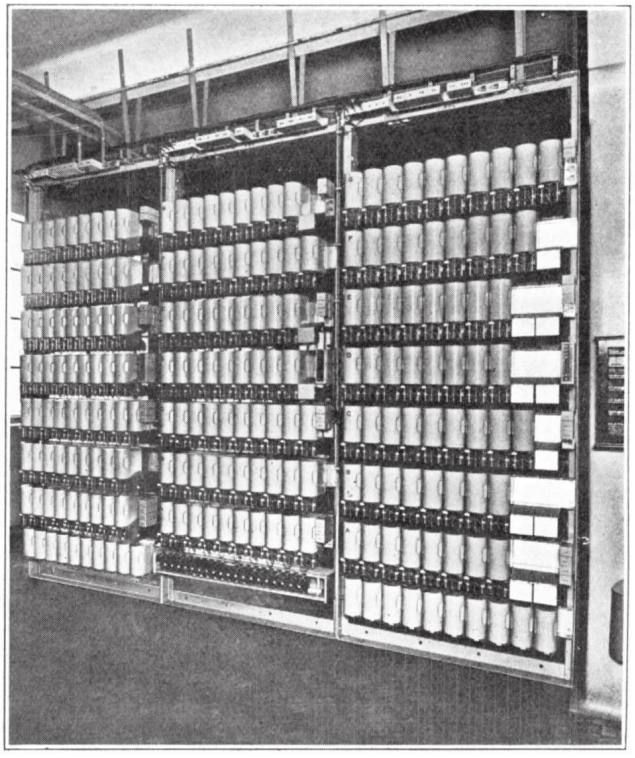


FIG. 5.—COMMON CONTROL SELECTORS AT BISHOPSGATE.

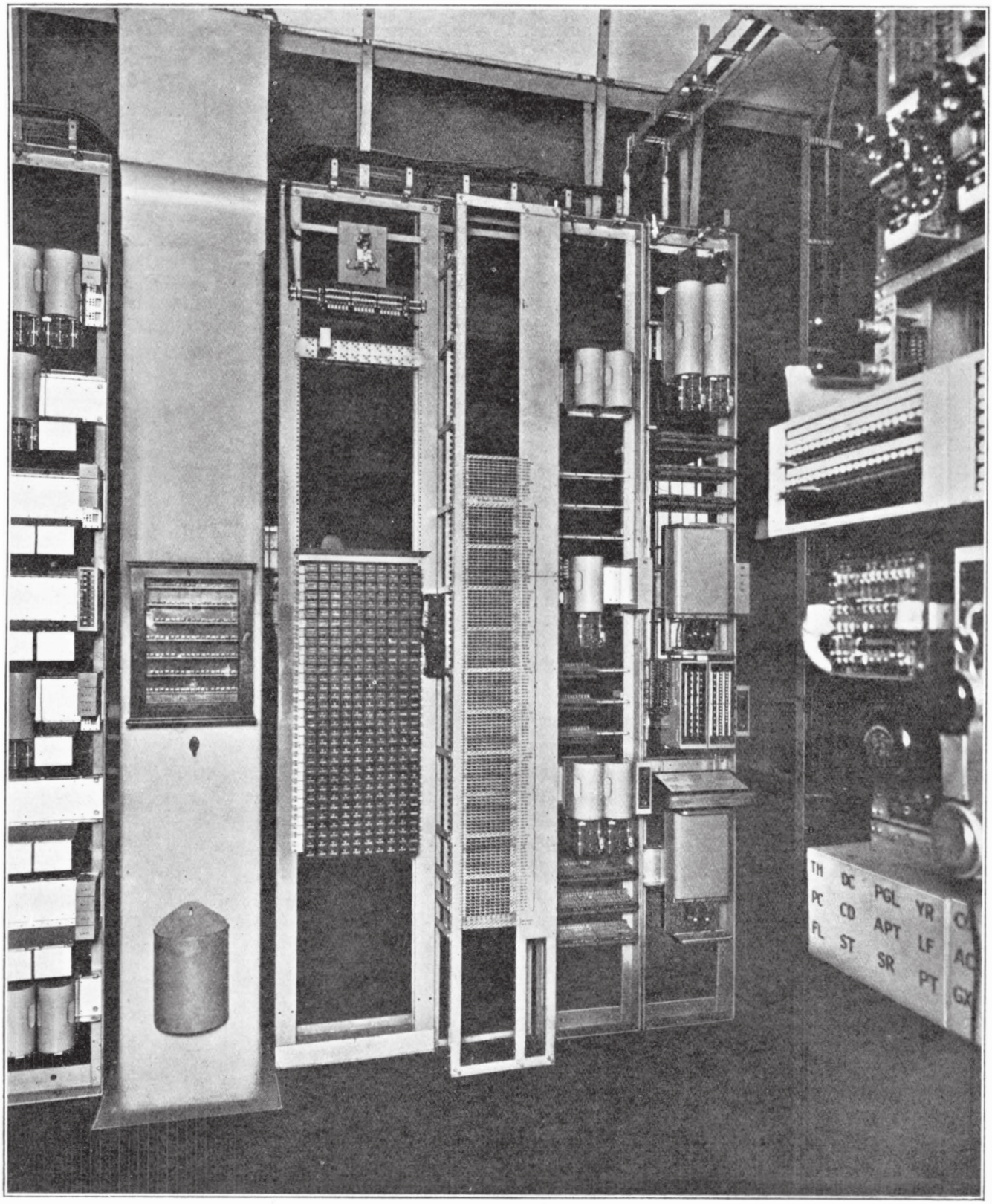


FIG. 6.—ROUTINER FOR COMMON CONTROL SELECTORS AND AUXILIARY EQUIPMENT FOR TRAFFIC INVESTIGATIONS.

physical disposition of the common control groups relative to the switches they control is such that the tracing of calls, usually a difficult and almost an impossible procedure on systems employing various forms of common control, is perfectly simple. For example, on a group selector rack containing say 8 shelves of 10 selectors each, there is also one shelf containing 10 common control relay sets. The wiring arrangements are such that the switches in position 1 on each shelf are each controlled by the common control relay set in position 1, and so on. This arrangement is, of course, of considerable importance for maintenance purposes. Furthermore, the order of testing by the preceding switch is arranged to be in the order A1, B2, C3, D4, E5, etc., thus ensuring that the common control relay sets are taken in order, and equalising the traffic over the shelves of switches.

An experimental trial equipment, consisting of three racks of common controlled 10/10 group selectors and a routiner, has recently been installed in Bishopsgate exchange. The purpose of this experimental trial equipment is primarily for traffic investigation. Auxiliary equipment in the form of traffic meters is therefore fitted for the purpose of obtaining traffic data, and means are provided whereby the holding times of both the common control relay sets and the switches can be ascertained at all stages of the calls. Ordinary exchange traffic is now passing through this equipment.

Fig. 5 shows a front view of the three selector racks, the shelf of uni-selectors being for the special purpose of applying varying holding times to simulate the traffic conditions on different ranks of switches.

Fig. 6 gives a view of the routiner and the auxiliary equipment employed for traffic investigations. The entire equipment has been handed over to the Department's engineers, to whom acknowledgements are due for the excellent facilities provided.

THE GRUB MENACE.

J. C. Dallow.

TELEPHONE engineers, in the course of their foremost duty of the preservation of line wires, frequently find themselves at war with nature. In fact, the engineer has good reason to say that in Dame Nature he has a malicious enemy who adopts every means at her command to cause breakdown of his plant.

Passing over the more violent methods such as damage by storms, nature also uses more insidious ways to interfere with the lines of communication. Among these is destruction by microbes and insect life. Engineers are well aware of the expensive plant and process necessary to preserve poles against wet rot, and the manufacturers of submarine cables are forced to take special precautions against the teredo worm, with its remarkable boring capabilities.

Another member of the insect world has now made its first serious onslaught against telephone equipment in this country. This is a type of clothes moth, which has launched its attack in the heart of the London Telephone System, at Tandem Exchange.

Occasional moths are not uncommon amongst wiring which has lain undisturbed for some time. There is at least one case where insect powder was used effectively against them on main frame jumper wires in one of the older manual exchanges; but in no previous instance is there any record of destruction similar to that which has been experienced at Tandem.

About the middle of January last it was noticed that jumper wires recovered from the main frame had patches on them where the insulation had been removed almost to the conductor itself. At first this was assumed to be due to abrasion, but closer examination, coupled with the discovery of some maggot-like insects, showed that the latter were responsible for the damage. It was found that a large number of wires under the

top layer in all parts of the frame were affected. A few moths were also seen, but these were far outnumbered by the grubs.

The matter was then taken up and in order to devise safe and certain methods of extermination it has been necessary to study the lives and habits of the insects.

Investigation has shown that the caterpillar is the larva of a moth belonging to the family of "Tineidæ," its name being "Tineola Bisselliella," the wool moth. Fig. 1 shows one of the

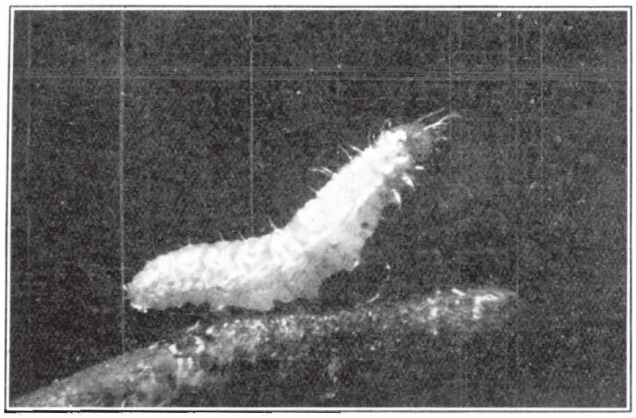


Fig. 1.
Photo by Dallow.

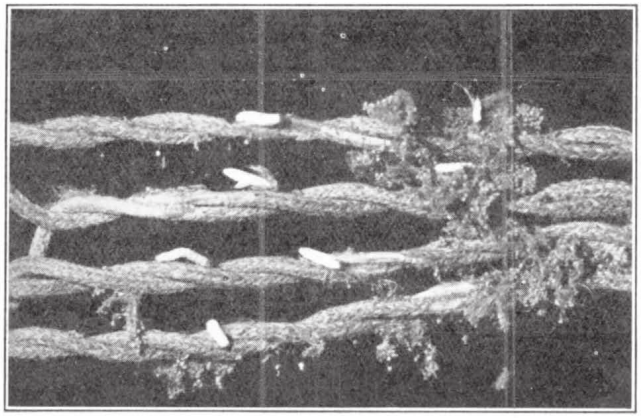


Fig. 2.
Photo by Dallow.

insects considerably magnified, the actual size being ¼ to ⅜ inch long. The head of the larva is brown and has a hard cuticle. In the front the head is provided with mandibles or jaws, which operate with a sideways movement, meeting like a pair of pincers. By means of these the grub cuts into and eats the woollen insulation of the wire. The head is also equipped with six simple eyes. These are, however, very imperfect, and appear as small spots on the head.

The body of the larva is white and is made up of a number of segments, each being equipped with hairs. Movement is accomplished with the aid of three pairs of legs near the head, each leg terminating in a small claw. Beneath the abdominal portion of the body are a number of circular protrusions, each equipped with minute hooks, which also assist the grub in its switch-back method of progression.

The caterpillar has an insatiable appetite and feeds continually. Very fortunately, it dislikes rubber, so that the jumper wires which have been attacked still possess the thin layer of rubber adjacent to the conductor. After digestion of the food has taken place, during which process it travels the whole length of the body, the insect discharges tiny slate-coloured pellets. These are turned to good use by the larva. It spins silk, in which it entangles the pellets, along with particles of dust and other rubbish, to form a mass of web. In this the insect conceals itself. Fig. 2 shows a colony of larvæ together with a mass of the collected material, which clings to the wires. The silk is extremely fine, and is only visible in a powerful light as a glistening filament. The photograph also shows patches on the wires where the insulation has been eaten away to the rubber coating.

After a period of gorging, which is usually about ten weeks, but which varies according to the temperature and general surroundings, the larva spins silk around itself and forms a chrysalis. At this stage the metamorphosis occurs. The sluggish, repulsive larva which formed the chrysalis emerges after about two weeks as a flimsy moth, its wings gleaming with a golden metallic sheen. In Fig. 2 a moth is shown on each of the inner wires. The main function of the female moth is to lay eggs, which will hatch out into larvæ. It deposits a number of eggs at a time and one moth in the course of its short existence of a week or two may lay as many as 150 of the minute eggs. Contrary to the feeding-by-biting method of the caterpillar, the moth can absorb food only by suction through a tube or proboscis situated in its head. It also has two fairly long antennæ, and is provided with two large compound eyes. Each of these is actually a number of little eyes amalga-

mated together, and under the microscope the whole looks similar to the surface of a blackberry.

The moth during its short life feeds very little or not at all. The energy for the transformation from larva to moth and the strength necessary to manufacture the eggs are provided mainly by the fattened larva before it enters the pupal stage. Since the moth can absorb nutrition only by suction, its food must be in a liquid state. The fact that so few moths have been seen at Tandem may perhaps be due to their premature death owing to the extremely dry conditions prevailing.

Several methods of extermination of the pests have been suggested and the investigations in this direction may be divided into three stages:

1. To arrest the reproduction of the larvæ.
2. To destroy all eggs, larvæ, chrysalides and moths in order to effect a complete cure.
3. To impregnate or alter the composition of jumper wire insulation so that the insects cannot feed on it, thereby avoiding recurrence of the trouble.

It is, of course, necessary to examine very closely every means of combating the insects, since it is easily possible for the remedy to be more harmful than the affliction.

At the time of writing the pests are being effectively checked by brushing and agitating the wires; all the insects and material which are dislodged are caught on sheets and burned.

To effect a complete cure it has been suggested that the whole main frame should be heated to a temperature of 60°C., and that state maintained for 48 hours. This, however, has been abandoned since it would probably melt the wax of the terminating cable forms, and might have an injurious effect on the insulation of the frame.

Experiments are now being conducted with various chemical sprays with the object of destroying all forms of the insects in the present attack, and rendering the insulation of the wire permanently fatal to the larvæ. Future specifications for the wire will probably include particulars of treatment of the wool which will prevent a recurrence of the trouble.

A peculiar feature of the attack is that, so far as is known, it is confined to the one exchange. This is the more remarkable since there are, apparently, many other frames which would be more conducive to the development of this type of insect than that at Tandem. The frame at Tandem is in a warm, dry atmosphere, and one side of it receives no daylight. It is, however, of modern design and all the wires are comparatively free, there being no thick, tangled mats of wire such as are frequently found in older types of frame. Work is also being constantly carried out and the wires are thereby disturbed.

SELLING BY TELEPHONE.

IT is well known that the average day calling rate is considerably lower in this country than in the United States. The Ratio of day to busy-hour traffic is also lower. A higher day calling rate would mean greatly increased prosperity for British telephones, not only in regard to revenue but also in regard to the rate of growth in the number of stations. In a system such as ours, in which the proportion of telephones working on the automatic principle is rapidly increasing, the ratio of day to busy hour traffic is of special importance because every additional call completed outside the busy-hour yields a higher proportion of profit than calls completed within the busy hour. Increased profits enable tariffs to be reduced; rapid extension of the system follows as a logical consequence.

Our object in stating these principles is to emphasize the importance of tendencies or developments in business methods or social habits which may have the effect of raising the day calling rate or improving the ratio of day to busy-hour traffic. Such tendencies should be discovered and encouraged in their earliest stages and their development should be followed with the keenest interest by all who are anxious for increased prosperity in the telephone industry.

After reading a remarkable book entitled "Selling by Telephone," a second edition of which has recently been published in the United States, we are convinced that such a tendency is now well advanced and definitely operative in that country. We are also convinced that when the new methods so ably described in this book are understood and that when the success attending their application in America becomes more widely known, it is highly probable that they will be taken up, developed along lines to suit British conditions and applied with equal success in this country with consequent advantage to the British Telephone System.

"Selling by Telephone" is not written with the direct object of bringing more business to the telephone system. It is written for Manufacturers, Wholesalers, Department Stores, Retailers, Financial Houses, Newspapers, etc., with the object of bringing prominently to their notice:—

> "An exceedingly active series of changes, all of which tend strongly to place emphasis upon that medium of universal personal communication, combining speed with low cost—the telephone. They tend, in short, to adopt, to co-ordinate, and to develop effective methods for making the fullest practical use of this device, second only in importance, and complimentary to advertising in sales work."

The author, Mr. J. George Frederick, is widely known in the United States as an authority on business subjects and as a business research man actively engaged in advancing business practice and the technique of salesmanship. He has carried out an extensive and careful investigation into the principles and practices of successful telephone salesmanship and in this book the results of his labours with many examples of actual results in various branches of business which have been realised in practice are set forth in concise and convincing language. He shows clearly that business men are only just beginning to realise the enormous importance of the telephone as a sales instrument and that as its value is better understood its use will rapidly increase. To quote the author's own words:—

> "Here then is a communication machine of national scope whose usefulness in national selling is only beginning to be appreciated. . . . . The extent to which the telephone can be used for this purpose would seem to depend largely upon the vision, initiative, and ability of sales managers to organise for telephone selling activities and establish policies which shall guide them along lines that will co-ordinate rather than upset the equilibrium of forces of efficient distribution. Promising beginnings have been made, but much remains in observing and completing the essential facts about demand creation by telephone, in classifying them, co-ordinating them, and establishing their mutual relations. The relation, however, between the requirements of efficient distribution and the adaptability of a nation-wide system of telephone communication is obviously such as to provoke rapid progress in the art of telephone selling."

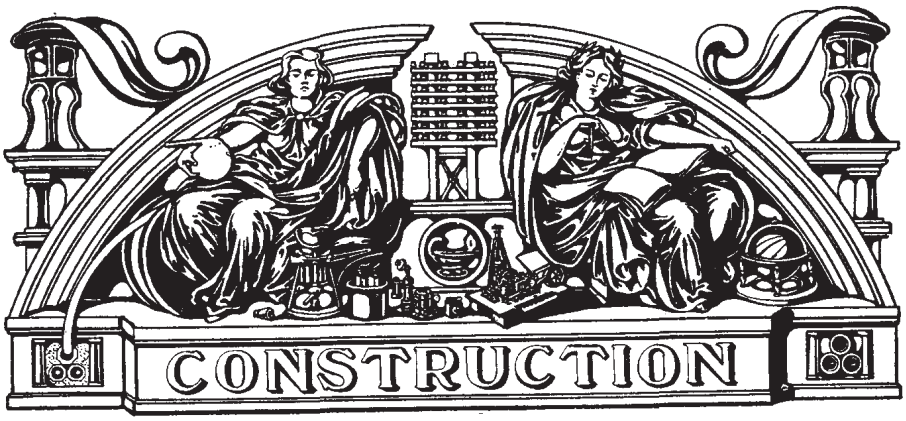
The telephone companies are, of course, co-operating in the new movement. In his description of what is known as the "Sequence Toll Call Plan" the author says:—

> "Very naturally one of the very first aids to telephone selling that suggests itself is an arrangement whereby the telephone company may facilitate in every possible way the handling of a large number of toll calls during a limited period. The telephone companies have now very thoroughly worked out plans for such assistance. They have taken upon themselves as much as possible of the labour and effort, in order to make telephone selling easier, faster, and better."

We wish that every Director and Sales Manager in this country would read and study this inspiring book. If, as a result, they decided to put the new methods to the test, they would find ready waiting for them an up-to-date nation-wide telephone system competent and eager to co-operate in the experiment.

"Selling by Telephone," by J. George Frederick. Published by Business Bourse, 80 West 40th Street, New York: 339 pp.: $4.00.

J.J.M.



REINFORCED CONCRETE POLES FOR TROPICAL USE.

E. HARPER, M.I.E.E., Mem.I.R.E.,
Chief Engineer, Ceylon Post & Telegraph Department.

THE Telegraph Engineer is faced with many difficulties in the Tropics which his confrere in more temperate zones escapes, and the supply of suitable posts on which to erect his wires is one of the most troublesome of them.

A plentiful supply of specially grown larch, pitch pine, red fir and cedar impregnated with creosote has solved the problem of a cheap and suitable wood post, having a long life, in most countries within the temperate zones, but the tropical problem is rather more complicated.

Creosoting has a much shorter effective life under a tropical sun with the torrential rains to assist in washing it out of the surface wood and no soft woods can then withstand the attacks of the myriads of termites or white ants, so that even if freightage charges did not rule out the creosoted pole as an economic proposition the white ants would do so.

Most indigenous tropical trees are of hard wood species which will not absorb creosote to any extent. A few of them are white ant proof, but even in these cases the sap wood is quite useless. As the trees are jungle grown, straight growth of suitable length and girth can rarely be obtained and the poles must be square sawn to the necessary dimensions. When the cost of felling, sawing and carting is added to the heavy depreciation charge, the total cost per pole is very high.

During the past eight years the development of the telephone service in Ceylon has been very rapid and the demand for poles far exceeded the supply of suitable local timber. As much of the development was in rural districts, where costs had to be reduced to an absolute minimum owing to the length of the lines, the economic aspect required most careful consideration.

Galvanised tubular iron poles are in many respects ideal for tropical conditions, but the post-war prices of these have until quite recently been so high as to make their use prohibitive in developing a cheap rural service.

Attention was, therefore, turned about six years ago to the possibilities of locally manufactured reinforced concrete poles. The writer was aware that the suitability or otherwise of this type of pole was a subject of controversy and that they had been tried and abandoned in many countries. An analysis of all the adverse comments and reports on the subject showed that in practically all the countries which had abandoned their use the climate was subject to large variations of temperature, severe frosts, snow storms, and high winds. The concrete developed hair cracks which permitted water to enter and attack the reinforcement. If frost supervened in these circumstances the result would naturally be the rapid disintegration of the concrete.

Ceylon is fortunately not subject to these

climatic extremes. Frosts never occur except very slightly in a few places up-country. The maximum daily range of shade temperature only amounts to about 14°, while the Observatory records for the past 10 years show only five occasions when the wind velocity exceeded 40 miles per hour and only two where it exceeded 60, in fact a velocity of 40 miles per hour may be considered very unusual.

Poles used for power transmission and distribution lines cannot as a rule be stayed owing to the dangers incidental thereto. They are, therefore, subject to very considerable horizontal stresses, varying rapidly due to the swinging of the wires, a condition of affairs admirably suited to the development of the hair cracks above referred to.

Poles used for telephone and telegraph lines are invariably stayed or strutted wherever anything more than a very slight angle occurs. All terminal poles are backstayed and on straight routes line stays are attached at frequent intervals to prevent any appreciable swing of the pole line as a whole. The bending stresses on such poles may therefore be regarded as quite small.

After taking into account all the known factors, it was decided in 1923 to experiment with reinforced concrete poles, in order to ascertain whether they could be manufactured locally at such prices as would compete satisfactorily with tubular iron poles and to obtain data for a suitable design.

Experimenting in reinforced concrete is decidedly slow work, owing to the length of time the finished article must be seasoned, and a period of two years was occupied in tests and experiments covering the following points:—

(1) Most suitable type of reinforcement.
(2) Design of reinforcement and composition of mixture to give maximum strength for minimum weight.
(3) Method of manufacture to give consistent results at lowest cost.

It was decided that the best results would be secured by concentrating the manufacture at one central depot in order that the work could be more thoroughly organised and checked. As all the material, excepting sand and granite chippings, were imported and landed at Colombo and distribution by road and rail was also most convenient at this point, this was obviously the most suitable site for the depot.

The experiments were satisfactorily concluded in 1925, and it was decided on the results obtained to go full speed ahead on the manufacture of concrete poles and abandon the use of wooden poles, excepting in certain special circumstances.

Portland cement was used for the mixture in all the poles turned out up to the end of 1929. Experiments were then made with some of the rapid setting aluminous cements. With these it was possible to obtain a pole of rather greater strength for the same weight and dimensions, while the period of seasoning could be considerably curtailed.

The aluminous cements are slightly more costly than Portland cement, but it was found that a mixture containing rather less of the former could be used, thus levelling up the cost of material. The speeding up of the seasoning process resulted in a small nett saving per pole, while the added convenience was considerable. Aluminous cement is, therefore, now used exclusively, and the following notes on manufacture are based on the use of this.

Moulds.—These are made of 1″ teak, the sides being keyed together as shown in the foreground of Fig. 1. With this method of building the moulds no difficulty has been experienced due to warping, and although the moulds have been in continuous use for five years the wood is only now beginning to lose its surface.

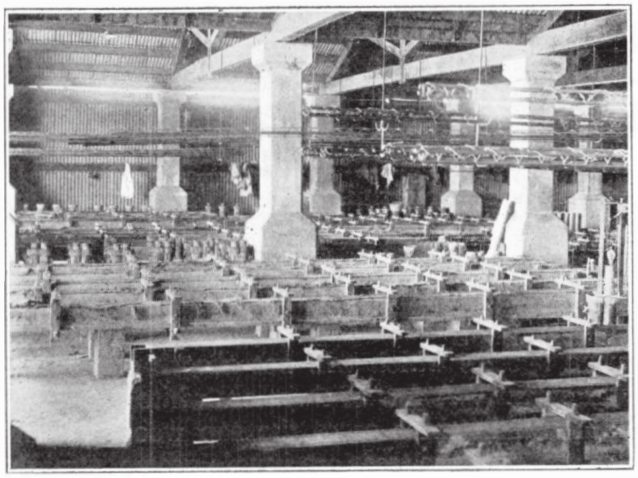


FIG. 1.—MOULDING SHOP.

The moulds provide for the number of arm slots shown in Table A, each with a 9/16″ bolt hole. On one side is fitted a die for the purpose of embossing a crown, "G.P.O.," length of pole and year of manufacture, the bottom of the letters "G.P.O." being 10 feet from the butt end of the pole. This provides the usual means of checking the depth of setting.

Reinforcement.—The reinforcement consists of mild steel bars of the number and dimensions indicated in Table A, spaced by means of a spiral of No. 8 S.W.G. iron wire, uniformly tapered to correspond to the taper required on the pole.

The bars are tied symmetrically to the outside of the spiral at alternate turns by means of No. 10 S.W.G. iron wire, the flat side of the bars being against the spiral. As large quantities of these tie wires are required, a machine was designed to cut and bend them to the required lengths. Short bars are provided to strengthen the reinforcement at the lower part of the pole, and are tied flat to the inside of the spiral, excepting in the case of the 18 feet poles where they are placed on edge to permit of the mixture being better worked in. Joints in the bars are not permitted. Fig. **2** shows details. The ends of

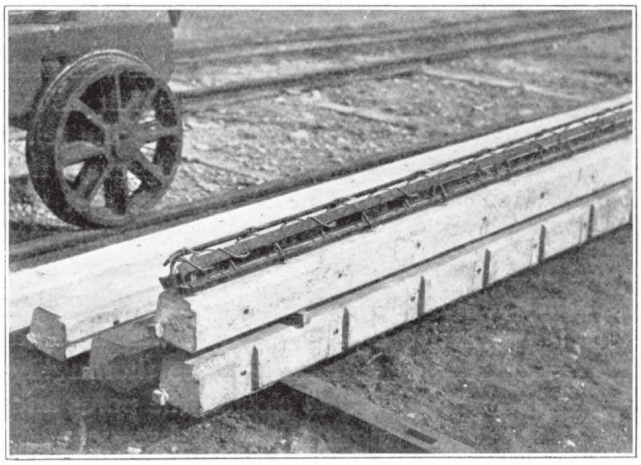


Fig. **2.**—Details of Reinforcement.

the long bars are turned inwards at the top to form a bearing for the saddle fitting referred to in the paragraph on casting.

The Mixture consists of one part "Ferrocrete" rapid setting cement, two parts river sand and three parts of ½″ metal. Owing to the high humidity of the Tropics fresh cement must be used which must be imported in sealed iron drums. Clean sand and metal, which should preferably be granite chippings, must be used. In order to secure a homogeneous mixture, it is very desirable to use a power-driven cement mixer. The mixture should be sufficiently fluid to allow a good cast to be made, but excess of water is to be avoided. The exact amount of water to be added is largely a matter of experience.

Casting.—The reinforcement is placed centrally in the mould and the dimensions provide for a covering of not less than ¾″ at all points. In working the mixture into the mould, great care must be exercised to avoid air holes and to ensure a smooth surface on all sides of the finished pole.

At the top of the pole, a bolt and nut with thimble are inserted to take a saddle fitting when necessary, the square head of the bolt projecting above the pole. Normally, it remains in position and is unscrewed and replaced by the saddle bolt when the latter is used.

Treatment after Casting.—The poles remain in the moulds four days after casting and during this period are kept moist. On the fourth day they are transferred to a pickling tank of water where they remain for a further period of ten days. They are then stacked and air-dried and seasoned for a period of approximately 50 days before being issued for use. Vide Fig. **3**. These periods are increased by about 50% in the case of poles of 30 feet in length or over and represent

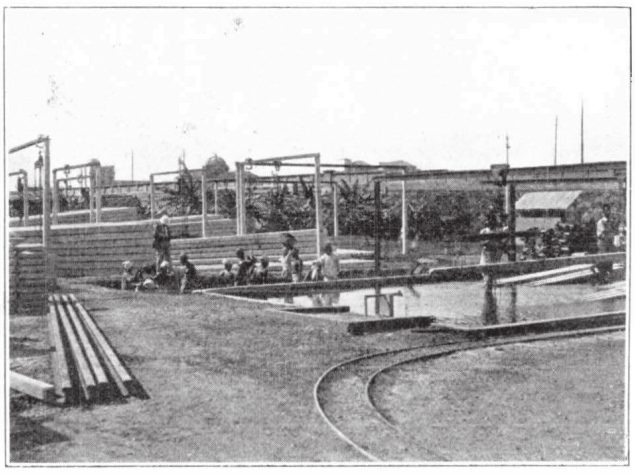


Fig. **3.**—Immersion Tank and Drying Ground.

a saving of 33 ⅓% on the time required for the same process using Portland cement.

Testing.—Frequent tests are made of the poles at 1 month, 3 months and 6 months in the following manner:—

They are rigidly clamped in a vertical position to a concrete base for a length corresponding to the depth of setting. On the other side of the concrete base is erected vertically a stout concrete pole, which is fitted with back stays to be perfectly rigid. A grooved pulley with ball bearings is fitted to the permanent pole and is adjustable in height to suit the pole under test. A wire rope is made off round the pole under test 1½ feet from the top and passed over the pulley. To the other end of the rope is fitted a straight vertical bar and holder for the testing weights. A divided scale, clamped at right angles to the permanent pole, provides means of measuring the deflection under various stresses and also enables the elasticity of the poles to be tested. The method is clearly shown in Fig. **4**.

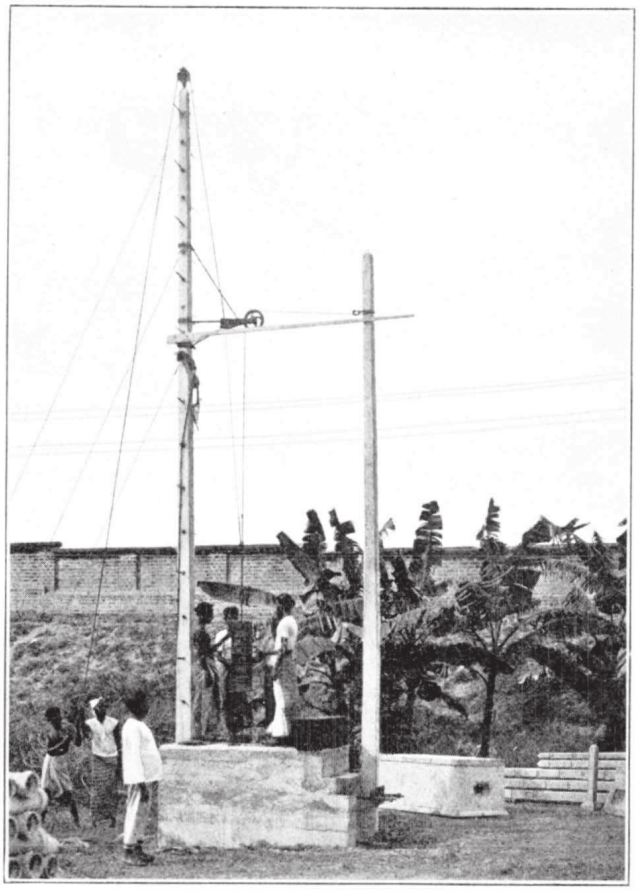


Fig. **4**.—Pole under test.

Table A gives the breaking stresses of the various poles after seasoning, while Fig. **5** indicates the breaking stresses for a typical 18 ft. pole at intermediate periods.

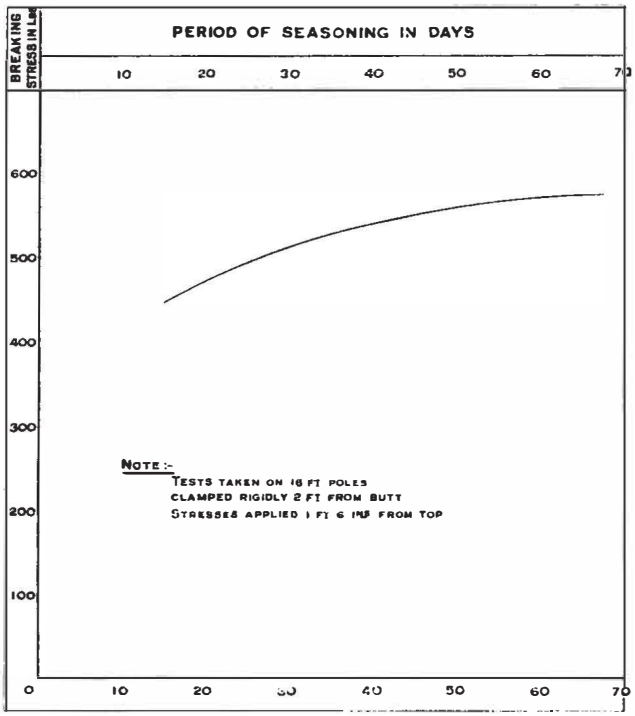


Fig. **5**.

When the manufacture of these poles was first commenced, some little doubt was felt as to whether the adhesion of the cement to the reinforcement was sufficiently perfect to prevent the formation of rust, in view of the fact that the appearance of hair cracks due to slight swaying of the poles was inevitable, thus giving access to the heavy rains and humidity of the Tropics.

As a preventive against this, it was made a rule for some time to tar the poles thoroughly on erection with a view to closing the pores and any cracks which might form. Subsequent experience, however, proved that this was an unnecessary precaution.

A number of poles which had stood in unfavourable positions for five years and had received no treatment of any kind were recently taken down and tested. It was found that their breaking stresses were higher than when originally erected. The concrete was then carefully chipped off the reinforcement and the latter was

found to be perfectly clean and in as good condition as when the pole was first made. Tarring was consequently stopped forthwith.

The manufacture of these poles in Ceylon gives employment to nearly 100 men, with an output of over 4,000 poles per annum, and nearly 30,000 poles are now in service.

Considerable interest has been shown by several other Colonial Administrations in the results obtained and in some cases it has been decided to follow the example of Ceylon.

It is, therefore, thought that the details now given may assist other Engineers who are faced with the same problems.

TABLE A.

DATA FOR REINFORCED CONCRETE POLES.

Length ft.	Dimensions of Sides. (Inches) Top	Bottom	Cubic contents Cu. Ft.	Weight lbs.	Spiral Reinforcement Diameter In. Top	Bottom	No. of Turns	Bar reinforcement. No. of Bars	Length Ft. In.	Cross section In.	Breaking stress. Load applied $1\frac{1}{2}$ ft. from top of pole.	Bending moment in foot lbs. at ground line.	No. of Arm Slots.
18 (Light)	3 × 3	$4\frac{1}{2}\times4\frac{1}{2}$	2.0	315	$1\frac{1}{2}$	3	54	4 2 2	17-10 7-6 4-0	$\frac{3}{4}\times\frac{1}{4}$ $\frac{3}{8}$ round $\frac{3}{8}$ "	364 lbs.	4925	2
18 (Heavy)	4 × 4	$5\frac{1}{2}\times5\frac{1}{2}$	2.8	450	$2\frac{1}{2}$	4	54	4 4	17-10 7-6	$\frac{3}{4}\times\frac{1}{4}$ $\frac{3}{4}\times\frac{1}{4}$	577 lbs.	7500	3
22	$4\frac{1}{2}\times4\frac{1}{2}$	7 × 7	5.0	820	$2\frac{5}{8}$	$5\frac{3}{4}$	64	4 4	21-10 9-00	$1\times\frac{1}{4}$ $\frac{3}{4}\times\frac{1}{4}$	800 lbs.	13200	4
24	$4\frac{1}{2}\times4\frac{1}{2}$	$7\frac{1}{4}\times7\frac{1}{4}$	5.5	900	$2\frac{5}{8}$	$5\frac{7}{8}$	69	4	23-10	$1\times\frac{1}{4}$	800 lbs.	14800	6
26	$4\frac{1}{2}\times4\frac{1}{2}$	$7\frac{1}{2}\times7\frac{1}{2}$	6.5	1008	$2\frac{5}{8}$	6	74	4	25-10	$1\times\frac{1}{4}$	800 lbs.	16000	6
30	$4\frac{1}{2}\times4\frac{1}{2}$	8 × 8	8.0	1302	$2\frac{5}{8}$	$6\frac{5}{8}$	84	4 4 4	14-00 29-10 18-00	$\frac{3}{4}\times\frac{1}{4}$ $1\times\frac{1}{4}$ $\frac{3}{4}\times\frac{1}{4}$	800 lbs.	18800	6

TABLE B.

REINFORCED CONCRETE POLES.

Average Cost of Manufacture in Ceylon.

	Lengths of Poles. 18 ft. L.	18 ft. H.	22 ft.	24 ft.	30 ft.
	s. d.	s. d.	s. d.	s. d.	s. d.
Materials	10 0	12 1	18 5	20 9	26 10
Labour *	4 2 (16)	4 2 (16)	6 0 (24)	6 5 (25)	7 10 (31)
	14 2	16 3	24 5	27 2	34 8
Overhead charges (including rent, depreciation, tools and supervision) 18%	2 $6\frac{1}{4}$	2 $11\frac{1}{2}$	4 $3\frac{1}{2}$	4 11	6 3
Total cost	16 $8\frac{1}{2}$	19 $2\frac{1}{2}$	28 $8\frac{1}{2}$	32 1	40 11

NOTE. 1. The cost of materials includes all freight and cartage charges to the site of manufacture.

NOTE 2. * The figures in brackets represent manhours excluding supervision.

NOTE 3. For purposes of comparison it may be stated that the latest prices of tubular steel poles delivered in Colombo are—22 ft. = 38/3 and 30 ft. = 55/3.

THE TRANSANDEAN TELEPHONE CABLE.

THE WORLD'S HIGHEST TELEPHONE LINE.

THE telephone conversation between H.R.H. the Prince of Wales and H.M. the King on February 22nd from Santiago de Chile to Buckingham Palace, London, was an impressive event not only for the public who read of it in the newspapers next day, but also for the royal participants in this extraordinary event. One indication of this was a request received by the Argentine telephone officials from London over the telephone for some photographs that might be shown to His Majesty, illustrating how such a communication could be possible.

Acting upon this request, the Union Telefonica prepared an album of photographs of the laying of the British-made underground cable across the Cumbre of the Cordillera, bound in parchment, and dedicated to the Prince of Wales. This magnificent album, typically Argentine in style, and bearing on the cover the coats-of-arms of Great Britain, Chile and Argentina, was delivered, in a case of glass and parchment, to the British Ambassador in Buenos Aires, Sir Ronald McCleay, P.C.K., C.M.G., by the general manager of the Union Telefonica, Mr. R. E. Petley, with the request that it be presented to the Prince.

On the first inside page of the album is a dedicatory parchment, bearing the coat-of-arms of the British heir and two miniature paintings of typical scenes connected with the installation of the Transandean cable, and with the following text:—

> "To His Royal Highness, the Prince of Wales, this album of photographs, showing the difficult task of laying across the summit of the Andes Mountains the British-made underground cable which has brought Chile within speaking distance of nine-tenths of the world's telephones, and by means of which he was enabled to talk from Santiago de Chile on Sunday, February 22, 1931, with His Majesty King George V. in Buckingham Palace, is most respectfully offered by
>
> The United River Plate Telephone Company, Ltd."

The Ambassador expressed great pleasure at receiving the album, which was added to the Prince's collection of momentos of his second South American tour.

The cable was made at the North Woolwich Factory of Messrs. Standard Telephones and Cables, Ltd. The first of its kind to be laid in South America, it is some 8½ miles in length and it is laid in a shallow trench at an altitude of 12,000 feet amongst the snow peaks of the mighty Andes, amidst scenes of majestic grandeur. To lay a telephone cable over the top of the Andes was a formidable task, and the fact that the difficulties were successfully overcome is a tribute to the daring, the resourcefulness and the perseverance of all concerned.

The cable was sent to the Transandean railway stations closest to the new telephone line. From these stations the cable drums were transported on motor lorries to points as near as possible to the scene of operations, following the tortuous route across the Andes. The last stage of transportation had to be carried out by workmen, since the terrain crossed by the new cable is inaccessible to vehicles. This was a task full of difficulties, on account of the nature of the ground and of the great altitude, factors which diminish considerably human powers of endurance.

One of the special characteristics of this cable is the resistance it affords to earthquake shocks, which are sometimes registered in the zone through which it runs. For this purpose special protection is necessary, consisting of two metal wrappings, coiled spirally in opposite directions, and separated by one wrapping of hessian and one of specially prepared cloth. Thanks to this protection, the cable can resist very violent torsions, and security against interruption is thus afforded.

The work of opening a trench for the laying of the new cable was finished in the summer. This proved a tremendous task, for the shortest route was taken, though wherever possible slopes and other difficulties which would have made it impossible to carry through the installation were avoided. On account of the rocky nature of the soil, a great part of the trench had to be opened by means of explosives. In certain parts of the route the snow, which in winter reaches a depth of 15 to 18 feet, had not disappeared, even in the summer season. As soon as the trench was completed, the laying, testing and jointing of the numerous sections of the new cable was put in hand. The installation was carried through

FIG. 1.—REAR VIEW OF THE CHRIST OF THE ANDES ON THE ARGENTINE-CHILEAN FRONTIER. In the background is the cable trench. The statue was erected to signify perpetual peace between the two countries.

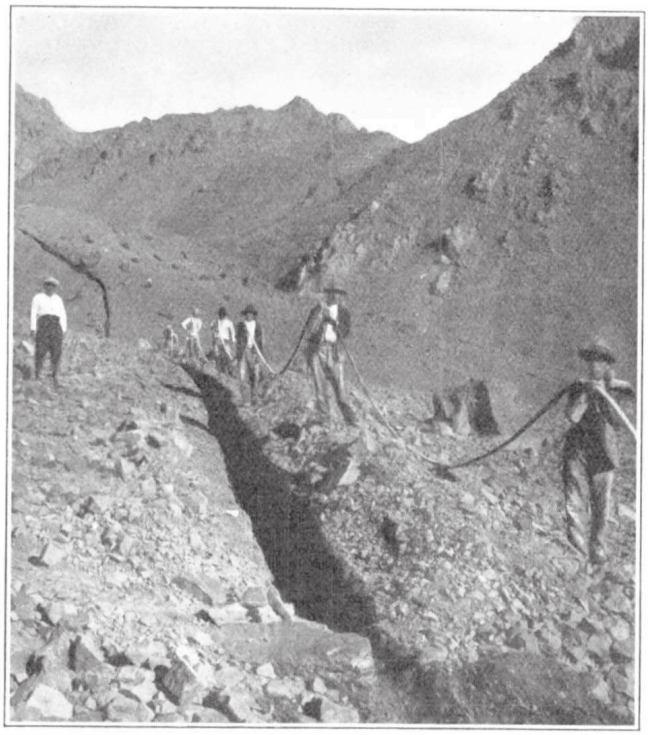


FIG. 2.—CARRYING CABLE FROM THE ROAD TO THE TRENCH.

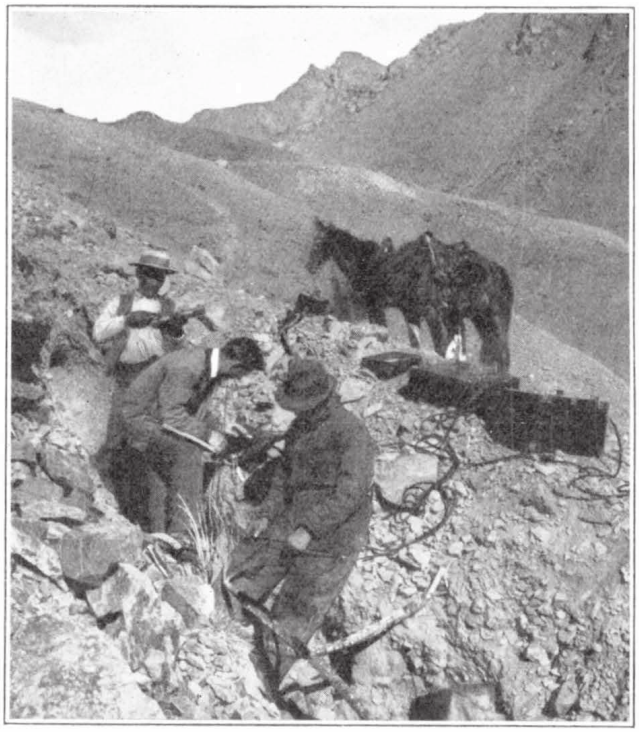


FIG. 3.—TESTING AND SPLICING AT A POINT IN THE HIGH ANDES.

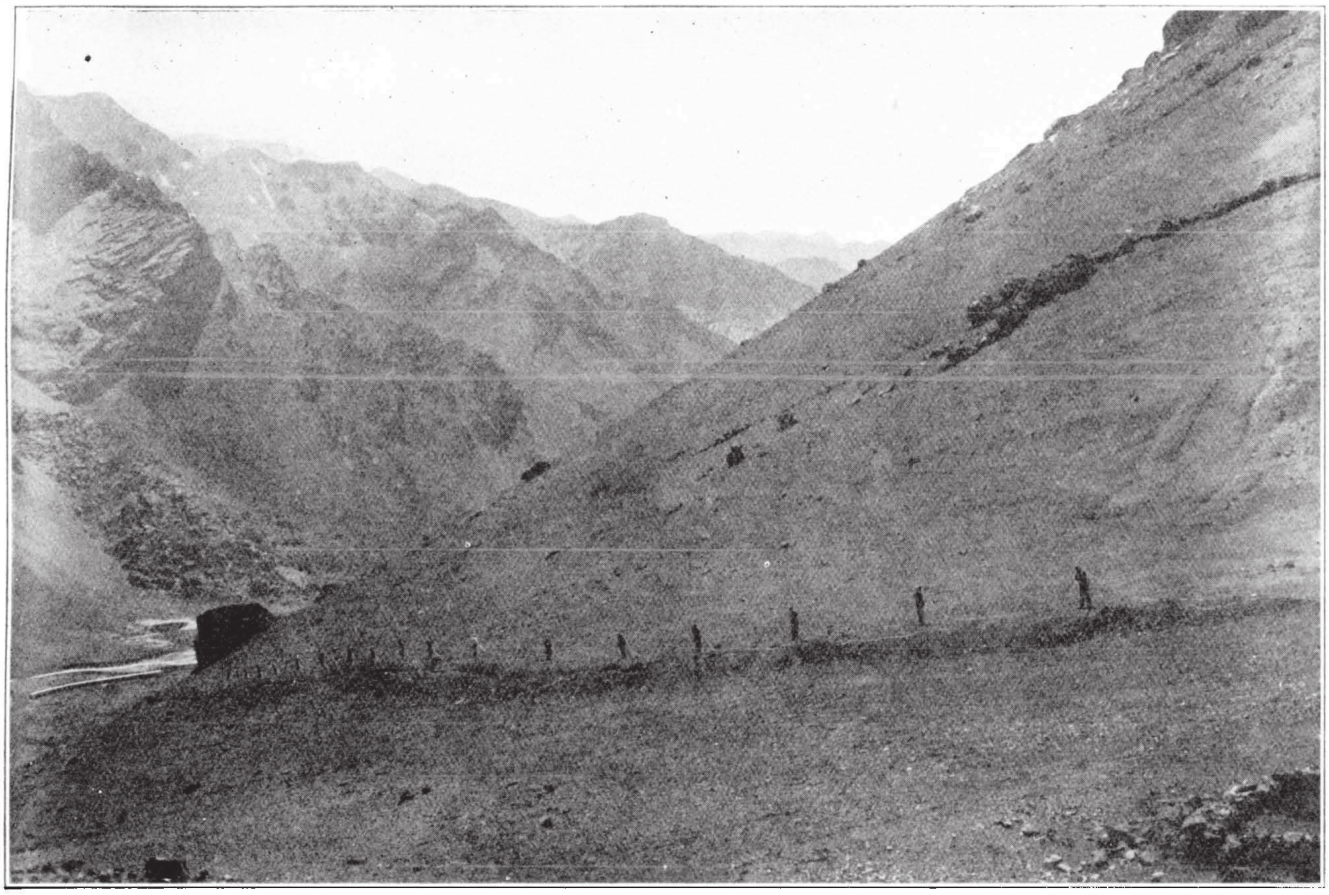


FIG. 4.—WORKMEN JUST FINISHED CLEANING THE TRENCH NEAR THE DIVIDE, ARGENTINE SIDE, BEFORE LAYING THE CABLE.

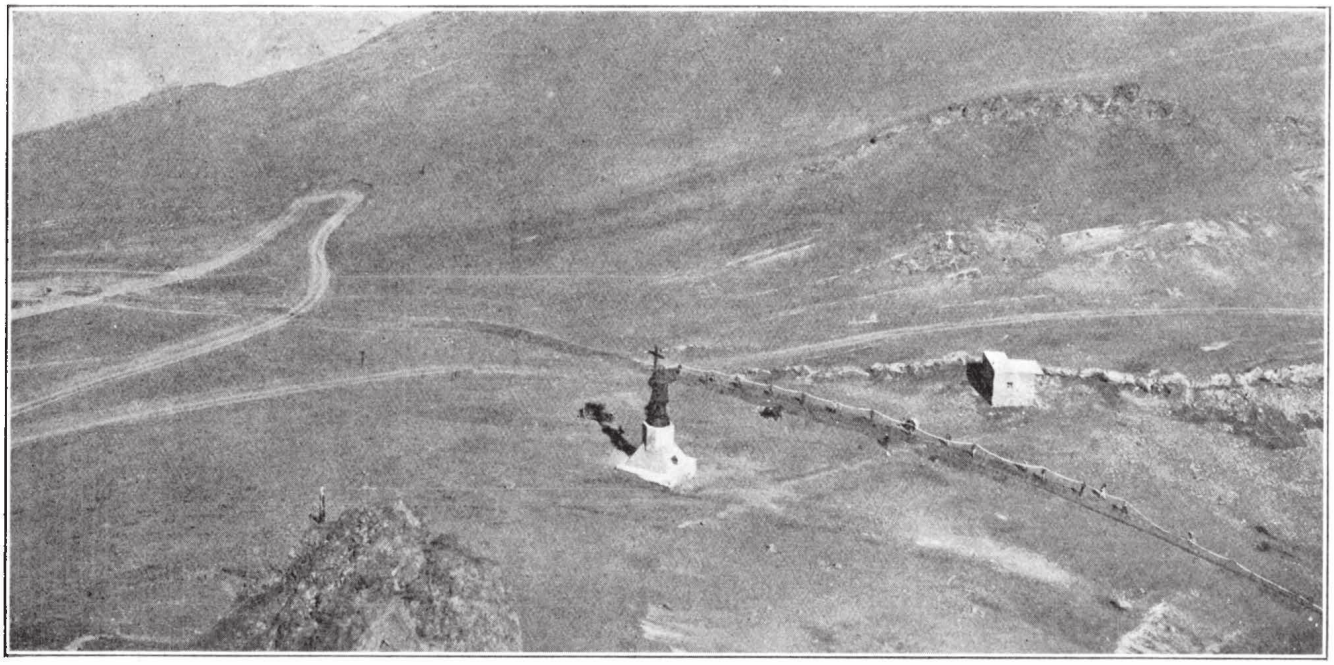


FIG. 5.—PLACING THE CABLE ACROSS THE DIVIDE, NEAR THE STATUE OF CHRIST.
To the left is the winding road down the Chilean side.

so rapidly, that in little more than one month after the completion of the trench it was finished and the new circuits were immediately put into action.

Some idea of the nature of the country and the magnitude of the task may be gathered from the illustrations accompanying this article.

OUTLINE NOTES ON TELEPHONE TRANSMISSION THEORY.

W. T. PALMER, B.Sc., Wh.Ex., A.M.I.E.E.

(SECTIONS 7—10).

SECTION 7—*continued.*

Coil-loaded Cables *(cont.)*

In underground and overhead cables the coils of all circuits are assembled in an iron case known as a " loading pot " (see Fig. **14**). The size of the coils is a large factor amongst those which influence the cost of coil loading. The importance of this factor has been reduced in recent years by the use of special dust-core coils and in some cases by the use of high permeability cores, such as permalloy, which give the required inductance and magnetic stability with a much smaller core than with the older wire and air-gap cores.

In submarine cables the practical question of coil-loading is a much more difficult problem and the cores of the inductance coils have to be assembled so as to occupy as little space as possible by being constructed with an overall shape nearly elliptical. (Fig **15**). A bulge is thus seen in the cable at loading-coil points, which must be of such diameter that when going over the sheave of the cable ship during laying or repair operations no damage is done to the coils or cable by undue strain.

II. Continuously-Loaded Cables.—First introduced by a Danish engineer named Krarup in 1902, this type of loaded cable is largely used for submarine cables. The loading consists of iron alloy wire of a few mils thickness, wound in a close spiral along the length of the copper conductor. A number of layers of loading wire may be used but, owing to increased electrostatic capacity of the loaded conductor and due regard being paid to the iron losses incurred, a limit is soon reached by increasing the inductance of the circuit in this manner.

Until the introduction of high permeability alloys with stable magnetic properties the maximum inductance per mile obtainable by the Krarup type of loading was of the order of 20 millihenries, but the recently laid telegraph cable

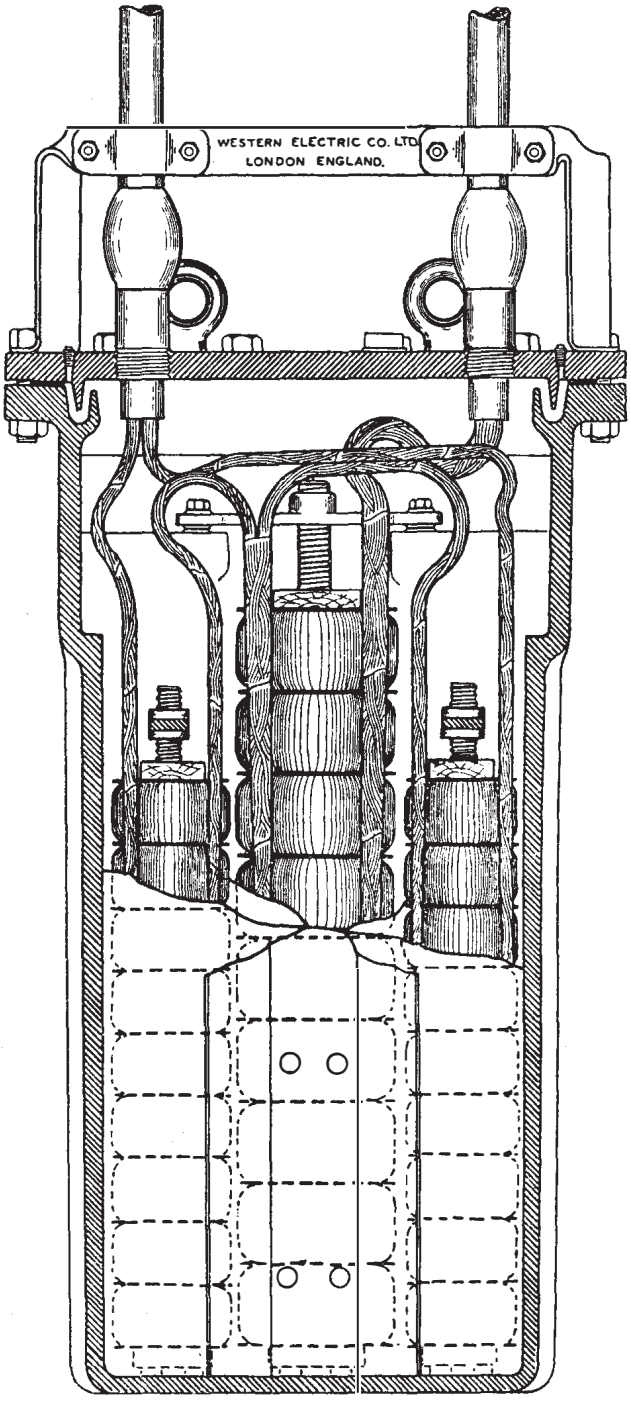


FIG. **14**.—SECTION OF LOADING COIL CASE, CONTAINING COILS FOR SIDE AND PHANTOM CIRCUITS.

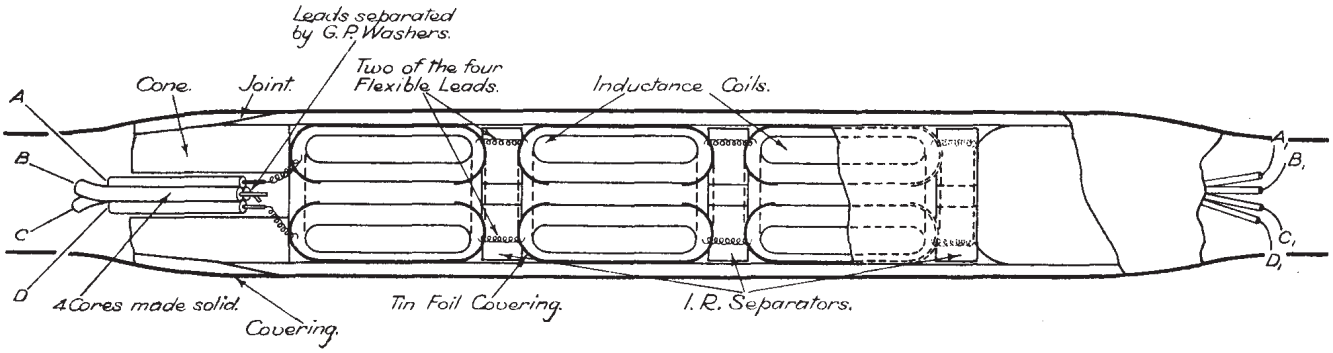


FIG. 15.— Loading Coil For Submarine Telephone Cable.

in the Pacific Ocean (between Fanning and Suva), continuously-loaded with permalloy, has an inductance of the order of 165 millihenries per nautical mile.

Principal Advantages of Continuous Loading:—

(1) When used for submarine cables the laying and repair operations are not more difficult than those for ordinary unloaded cables.
(2) The impedance-frequency characteristics can be made smoother than for coil-loaded cables.
(3) Useful for insertion in short U.G. cables between two aerial lines.
(4) Cheaper maintenance.

Principal Disadvantages of Continuous Loading:—

(1) For a given low attenuation a continuously-loaded cable is at present more expensive to construct than a coil-loaded cable.
(2) Cannot be applied to existing unloaded circuits.
(3) Liable to increased cross-talk produced by inductance unbalance due to age, excessive testing currents, etc.

Further References for Section 7:—

"Electrical Communication," Vol. 4, No. 1 (1925).—"The Loaded Submarine Cable," by D. E. Buckley.
Journal I.E.E., Vol. 67, April, 1929.—"The Continuously Loaded Telegraph Cable," by Foster, Ledger and Rosen.

SECTION 8.

Artificial Lines or Equivalent Networks— T and π Circuits.

It is frequently necessary for test purposes, for comparison or analysis, etc., to replace a complicated circuit by a simple one. A transmission line having uniformly distributed constants is a complex electrical circuit having resistance and inductance elements in series, and capacitance and leakance elements in shunt—See Fig. 4, Section 2. Simple networks may be constructed to represent, in various degrees, such actual transmission lines and are known as *artificial* circuits. There are two principal classes:—

(*a*) "Nominal" circuits.
(*b*) "Equivalent" circuits.

It will be seen from what follows that, actually, (*a*) is a particular case of (*b*).

(*a*) Nominal Artificial Circuits.

One such circuit can be obtained by assuming the shunt elements (G and C) to be concentrated in the middle of the line and one-half the total line conductor resistance and inductance concentrated on either side of it.—Fig. **16** refers. This is usually simplified further by assuming the R and L normally in the two wires of the line to be lumped in a single wire and is then usually termed a "*nominal* **T**-*circuit*" from its shape. See Fig. **17**.

Another type of nominal circuit can be built by assuming the total G and C to be split into two equal parts and lumped, one at each end of the line, with the total R and L lumped between

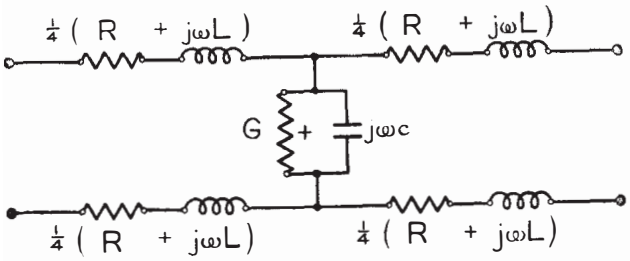


FIG. 16.

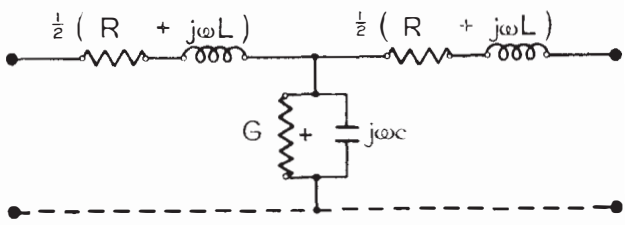


FIG. 17.— *Nominal T-Circuit.*

them. See Figs. **18** and **19**. The latter is termed a "*nominal* **π**-*circuit*" from its likeness to the letter π.

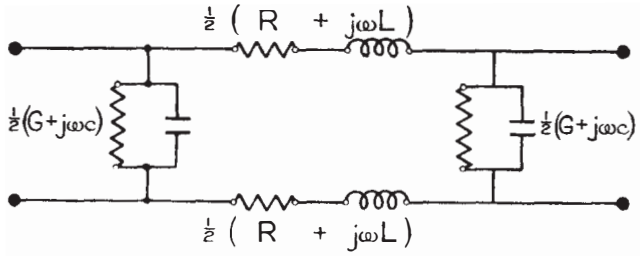


FIG. 18.

Such nominal circuits are *only approximations*, since with the same impressed voltage (at any particular frequency) on line and network the network does not give actual line receiving-end conditions, and hence the transmission effect is not exactly equivalent to that of the actual line. On the other hand, with equal impressed voltage at a definite frequency, a **T**-circuit and also a **π**-circuit can usually be constructed to give actual line-end conditions and such circuits are known as "*equivalent circuits.*" The sum of the R, L, G and C of the equivalent circuit will not necessarily be equal to the total R, L, G and C respectively of the line it represents and the method of obtaining the necessary branch impedances required is as follows:—

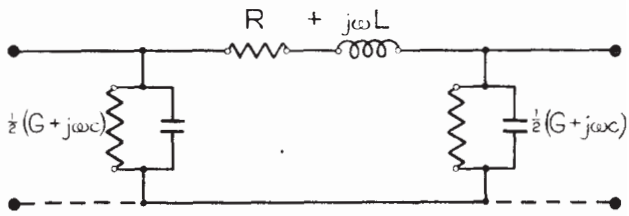


FIG. 19.— *Nominal π-Circuit.*

(*b*) Equivalent Networks.

1. *Equivalent* **T**-*Circuit.*

Since most lines are terminated by a receiving impedance as nearly as possible equal to Z_0 (to avoid reflection effects, etc.) the following networks are made to represent any given *finite length of uniform line* on the assumption that the receiver impedance equals Z_0 in modulus and angle. Further, since the magnitudes of the branches Z_1 and Z_2 change with frequency, then these single section networks *only exactly represent the line at the one definite frequency* for which Z_1 and Z_2 are calculated. See Fig. **20**.

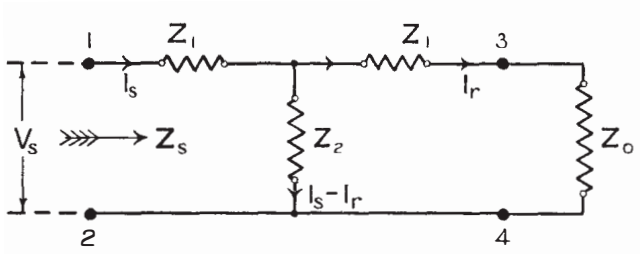


FIG. 20.

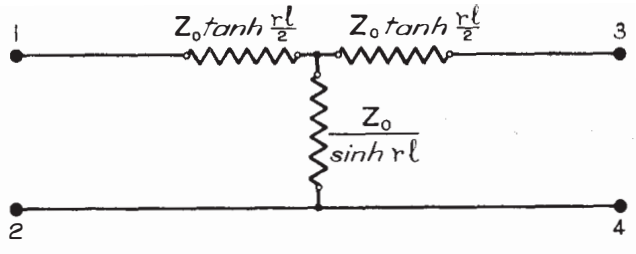


FIG. 21.— *Equivalent T-Circuit.*

Let Z_1 = impedance of series arms

Z_2 = ,, ,, shunt branch

Z_s = ,, measured at terminals 1—2, when the equivalent -T is closed by Z_0

I_s = sent current at terminals 1—2

I_r = received current at terminals 3—4 and flowing through Z_0.

Since Z_2 is in parallel with $Z_1 + Z_0$:—

$$Z_s = Z_1 + \frac{Z_2 (Z_1 + Z_0)}{Z_1 + Z_2 + Z_0} \quad \ldots\ldots(1)$$

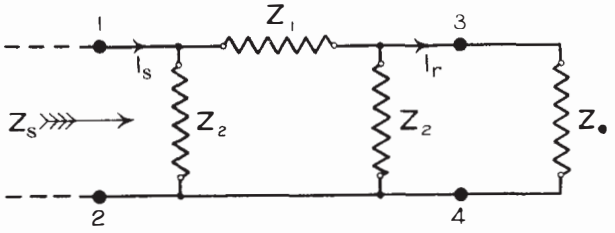


FIG. 22.

But if the network, 1—2 to 3—4, is to behave as an actual uniform line of length, l, and propagation constant, γ, terminated by Z_0, then :

$Z_s = Z_0$ (See pp. I. of Section 3 of Notes).

Hence equation (1) above becomes :—

$$Z_0 = Z_1 + \frac{Z_2 (Z_1 + Z_0)}{Z_1 + Z_2 + Z_0} \quad \ldots\ldots(2)$$

Again, if the network is to behave as a uniform line closed by Z_0, we have—from equation (4) of Section 3—

$$\frac{I_r}{I_s} = e^{-\gamma l}$$

But $I_r = \dfrac{Z_2}{Z_1 + Z_2 + Z_0} \times I_s$ and hence :—

$$\frac{Z_2}{Z_1 + Z_2 + Z_0} = e^{-\gamma l} \quad \ldots\ldots(3)$$

Combining equations (2) and (3)—

$$Z_0 = Z_1 + e^{-\gamma l} (Z_1 + Z_0) \quad \ldots\ldots(4)$$

$$\text{or } Z_1 = Z_0 \left(\frac{1 - e^{-\gamma l}}{1 + e^{-\gamma l}} \right) = Z_0 \left(\frac{e^{\frac{\gamma l}{2}} - e^{-\frac{\gamma l}{2}}}{e^{\frac{\gamma l}{2}} + e^{-\frac{\gamma l}{2}}} \right)$$

$$\therefore Z_1 = Z_0 \tanh \frac{\gamma l}{2} \quad \ldots\ldots(5)$$

From equations (3) and (4) :—

$$Z_0 \left(1 - \frac{1 - e^{-\gamma l}}{1 + e^{-\gamma l}} \right) = Z_2 (1 - e^{-\gamma l})$$

$$\therefore Z_2 = \frac{Z_0}{\sinh \gamma l} \quad \ldots\ldots(6)$$

Therefore, the equivalent **T**-network of a line length, l, closed by Z_0 and of propagation constant, γ, is as shown in Fig. **21**.

2. *Equivalent* **π**-*Circuit*. See Fig. **22**.

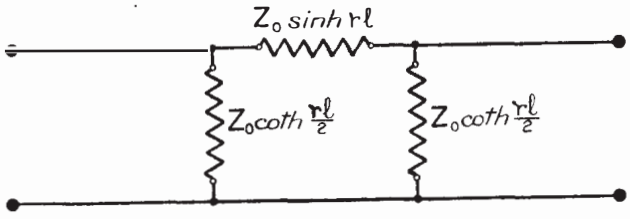


FIG. 23.— Equivalent π-Circuit

Z_2 = shunt branch impedances,

Z_1 = series arm impedance,

I_s = current entering 1—2,

I_r = current leaving 3—4,

Z_0 = terminating impedance,

$$\text{Then } Z_s = Z_0 = \frac{Z_2 \left\{ Z_1 + \dfrac{Z_2 Z_0}{Z_2 + Z_0} \right\}}{Z_2 + Z_1 + \dfrac{Z_2 Z_0}{Z_2 + Z_0}} \quad \ldots\ldots(7)$$

Which can be written :—

$$Z_0^2 = \frac{Z_1 Z_2^2}{Z_1 + 2Z_2} \quad \ldots\ldots(8)$$

$$\text{Again } \frac{I_r}{I_s} = e^{-\gamma l} = \frac{Z_2}{Z_2 + Z_0} \times \frac{Z_2}{Z_1 + Z_2 + \dfrac{Z_2 Z_0}{Z_2 + Z_0}} \quad \ldots\ldots(9)$$

From equations (7) and (9) :—

$$Z_0 = \frac{Z_1 Z_2}{Z_2 (e^{\gamma l} - 1) - Z_1}$$

and writing $(e^{\gamma l} - 1) = d$ in this equation it becomes :—

$$Z_1 = \frac{Z_0 Z_2 \cdot d}{Z_2 + Z_0} \quad \ldots\ldots(10)$$

Substituting in equation (8), the value of Z_1 found in equation (10):—

$Z_2^2 \cdot d - 2Z_2Z_0 - Z_0^2(d + 2) = 0$ which is a quadratic in Z_2. Solving for Z_2:—

$$Z_2 = \frac{2Z_0 \pm \sqrt{4Z_0^2 + 4Z_0^2 d(d+2)}}{2d}$$

Since d is always positive,

$$\therefore Z_2 = Z_0\left(\frac{2+d}{d}\right) = Z_0\left(\frac{e^{\frac{\gamma l}{2}} + e^{-\frac{\gamma l}{2}}}{e^{\frac{\gamma l}{2}} - e^{-\frac{\gamma l}{2}}}\right)$$

$$\therefore Z_2 = Z_0 \coth \frac{\gamma l}{2} \quad \ldots\ldots\ldots\ldots(11)$$

From equation (10), substituting $d = e^{\gamma l} - 1$ and $Z_2 = Z_0 \coth \frac{\gamma l}{2}$, then:—

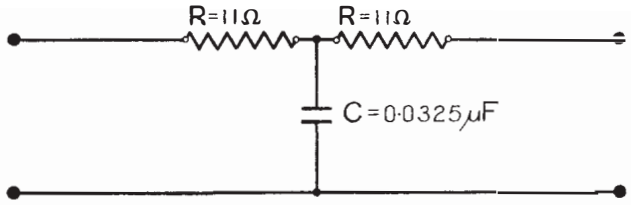


FIG. 24.— *Nominal T.*

$$Z_1 = \frac{Z_0(e^{2\gamma l} - 1)}{2e^{\gamma l}} = Z_0\left(\frac{e^{\gamma l} - e^{-\gamma l}}{2}\right)$$

$$\therefore Z_1 = Z_0 \sinh \gamma l \quad \ldots\ldots\ldots\ldots(12)$$

Therefore, the equivalent π-network of a line length, l, closed by Z_0 and of propagation constant, γ, is as shown in Fig. **23**.

Note.—If l is so small that

$$\sinh \gamma l \rightarrow \gamma l \text{ and}$$
$$\tanh \gamma l \rightarrow \gamma l$$

then, equations (5), (6), (11) and (12) reduce to the corresponding nominal circuit values. Hence, a criterion by which it can be determined whether a nominal circuit or equivalent circuit should be used is found in the degree of equivalence to γl of $\sinh \gamma l$ and $\tanh \gamma l$.

Example.—Find **T**-networks which shall represent at 5000 rads./sec., (*a*) $\frac{1}{2}$ mile, (*b*) 40 miles, of a circuit with loop mile constants R = 44 ohms, C = 0.065 microfarad. Neglect natural inductance of the line and leakance.

Considering (*a*). The propagation constant $\gamma = 0.1195 \angle 45°$; $\gamma l = 0.05975 \angle 45°$; $\sinh \gamma l \fallingdotseq 0.05979$ and $\tanh \gamma l \fallingdotseq 0.05968$. It will be seen that $\gamma l \rightarrow \sinh \gamma l \rightarrow \tanh \gamma l$, and hence

$$Z_1 = Z_0 \cdot \frac{\gamma l}{2} = \frac{(R + j\omega L) \times \frac{1}{2}}{2} = \frac{R}{4}$$

since L = 0, *i.e.*, $Z_1 = 11$ ohms.

$$\text{Also } Z_2 = \frac{Z_0}{\gamma l} = \frac{1}{(G + j\omega C) \times \frac{1}{2}} = \frac{1}{j\omega \frac{C}{2}}$$

since G = 0, $Z_2 = -j\,6150$ ohms.

In such a case, therefore, the nominal circuit arrangement shown in Fig. **24** would be sufficiently accurate for practical purposes and would, of course, represent the line at all frequencies.

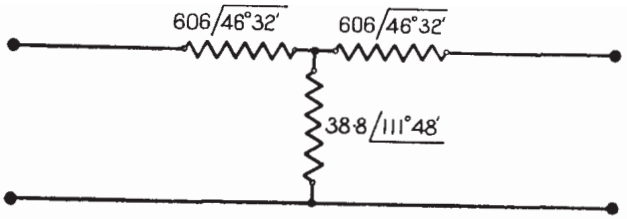


FIG. 25.— *Equivalent T.*

Considering (*b*). $\gamma = .1195 \angle 45°$

$\gamma l = 4.78 \angle 45°$

$\sinh \gamma l = 14.74 \angle 203°12'$

$\tanh \frac{\gamma l}{2} = 1.064 \angle 1°32'$

$Z_0 = 570 \angle 45°$

Hence $Z_1 = 606 \angle 46°32'$

$Z_2 = 38.8 \angle 111°48'$

It is interesting to note that this particular **T**-network (Fig. **25**) is a case of a "*mathematical equivalent*" only (useful in the solution of a more complicated problem) and cannot be physically constructed as the *resistance portion of Z_2 is negative*. In such a case a π-network is sometimes physically possible, though not always so, and should be calculated if an actual network is sought.

3. *Expressions for Characteristic Impedance and Propagation Constant of Equivalent Networks in Terms of the Branch Impedances Z_1 and Z_2. (These results are of great importance).*

Equivalent **T**-*Circuit.*

By considering Fig. **20**:—

$$Z_0 = Z_1 + \frac{Z_2(Z_1 + Z_0)}{Z_1 + Z_2 + Z_0}$$

$$\therefore \quad Z_0^2 = Z_1^2 + 2Z_1Z_2$$

$$\therefore \quad Z_0 = \sqrt{2Z_1Z_2\left(1 + \frac{Z_1}{2Z_2}\right)} \qquad \ldots\ldots\ldots\ldots(13)$$

Again, if P = propagation constant of one section of an infinite number of recurrent symmeterical networks (P = γl if each section represents l miles of cable closed by Z_0 and having a propagation constant γ per mile).

$$\text{Then } P = \log_e \frac{I_s}{I_r} = \log_e \frac{Z_1 + Z_2 + Z_0}{Z_2}$$

Substituting for Z_0 from equation (13):—

$$\therefore \quad P = \log_e \left\{ \frac{Z_1 + Z_2}{Z_2} + \frac{\sqrt{2Z_1Z_2\left(1 + \frac{Z_1}{2Z_2}\right)}}{Z_2} \right\} \qquad \ldots\ldots\ldots\ldots(14)$$

By putting $x = \dfrac{Z_1 + Z_2}{Z_2}$ equation (14) becomes:—

$$P = \log_e (x + \sqrt{x^2 - 1}) = \cosh^{-1} x$$

$$\therefore \quad P = \cosh^{-1}\left(1 + \frac{Z_1}{Z_2}\right) \qquad \ldots\ldots\ldots\ldots(15)$$

Equivalent π-*Circuit.*

By considering Fig. **22**:—

$$Z_0 = \frac{Z_2\left(Z_1 + \frac{Z_2Z_0}{Z_2 + Z_0}\right)}{Z_2 + Z_1 + \frac{Z_2Z_0}{Z_2 + Z_0}}$$

$$\therefore \quad Z_0 = \sqrt{\frac{Z_1Z_2}{2\left(1 + \frac{Z_1}{2Z_2}\right)}} \qquad \ldots\ldots\ldots\ldots(16)$$

Again, as in the case of recurrent **T** sections, let there be an infinite number of π-sections, each with propagation constant P. Then:—

$$P = \log_e \frac{I_s}{I_r} = \log_e \frac{(Z_1 + Z_0)\left(Z_1 + Z_2 + \frac{Z_2Z_0}{Z_2 + Z_0}\right)}{Z_2^2}$$

$$= \log_e \frac{Z_1Z_2 + Z_2^2 + Z_0(Z_1 + 2Z_2)}{Z_2^2}$$

Substituting for Z_0 from equation (16):—

$$\therefore \quad P = \log_e \left\{ \frac{Z_1 + Z_2}{Z_2} + \sqrt{2Z_1Z_2\left(1 + \frac{Z_1}{2Z_2}\right)} \right\} \qquad \ldots\ldots\ldots\ldots(17)$$

which is the same as equation (14).

$$\therefore \quad P = \cosh^{-1}\left(1 + \frac{Z_1}{Z_2}\right) \qquad \ldots\ldots\ldots\ldots(18)$$

NOTE.—Expressions (15) and (18) are identical, and therefore the propagation constant per section is the same whether the structure is considered as an infinite number of T or π-networks.

SECTION 9.

Attenuation Constant of Lump-loaded Line.—Campbell's Formula.—"Cut-off" Frequency.

Let d miles be the coil spacing. Then each loading coil section can be represented by a **T**-network.

Let γ = propagation constant per mile of unloaded cable

γ' = propagation constant per mile of loaded cable

Z_c = loading coil impedance

Then, from equation (15) of Section 8:—

$$\text{Cosh } \gamma d = 1 + \frac{Z_1}{Z_2} = \frac{Z_1 + Z_2}{Z_2} \qquad \ldots\ldots\ldots\ldots(1)$$

$$\therefore \text{ Also } \cosh \gamma' d = 1 + \frac{Z_1 + \frac{1}{2}Z_c}{Z_2}$$

$$= \frac{Z_1 + Z_2}{Z_2} + \frac{Z_c}{2Z_2} \qquad \ldots\ldots\ldots\ldots(2)$$

Hence from (1) and (2), and since $Z_2 = Z_0/\sinh \gamma d$,

$$\text{Cosh } \gamma' d = \cosh \gamma d + \frac{Z_c}{2Z_0} \sinh \gamma d \quad \ldots\ldots(3)$$

which may be written

$$\gamma' (\text{Loaded Line}) = \frac{1}{d} \cosh^{-1} \left\{ \cosh \gamma d + \frac{Z_c}{2Z_0} \sinh \gamma d \right\} \quad \ldots\ldots(4)$$

and is Campbell's formula giving rigorously the propagation constant per mile of loaded cable in terms of the propagation constant of the unloaded conductor (γ), the impedance of the loading coils (Z_c) and unloaded conductor (Z_0) and the distance between coils (d).

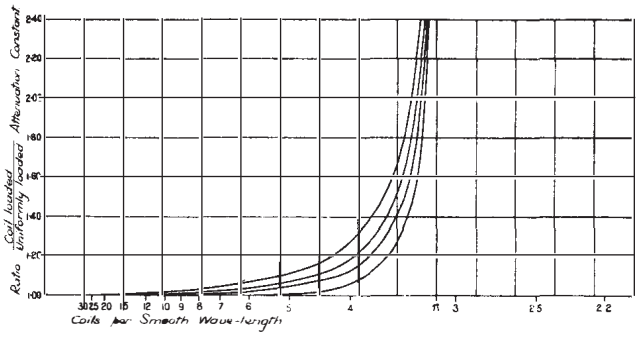


FIG. 26. This family of curves has been drawn for different weights of conductor by using Campbell's formula for lump loaded line and equation (18) of Section 2 for a smooth line, to obtain the ratios given by the ordinates.

This formula usually involves much laborious evaluation, unless specially prepared charts of complex hyperbolic functions are used, and for practical determination of γ' various other approximate formulæ have been evolved. As an example of such approximate formulæ see H. F. Mayer in *Telegraphen and Fernsprechtechnik, Part 6, 1927*. See also References at end of Section 9.

Note 1.—Referring to Campbell's formula, equation (4), if values of γ' are plotted against frequency it will be found that in all cases γ' experiences an enormous and sudden increase when a value of frequency is approached such that :—

$$\omega = \frac{2}{d\sqrt{CL_1}} \quad \ldots\ldots(5)$$

where L_1 = total inductance per mile including coil, and C = total capacity per mile. See Fig. **26**. At this critical or " *cut-off* " *frequency* the wave-length of the circuit is related to d, the spacing as follows :—

Let ω_c be the cut-off pulsatance,

$$\alpha \fallingdotseq \omega_c \sqrt{CL_1} \quad \ldots\ldots(6)$$

and $$\lambda = \frac{2\pi}{\alpha} \quad \ldots\ldots(7)$$

At the critical frequency,

$$\omega_c = \frac{2}{d\sqrt{CL_1}} \quad i.e., \quad \sqrt{CL_1} = \frac{2}{\omega_c d}$$

Hence $$\lambda = \frac{2\pi}{\omega_c \sqrt{CL_1}} = \pi d \quad \ldots\ldots(8)$$

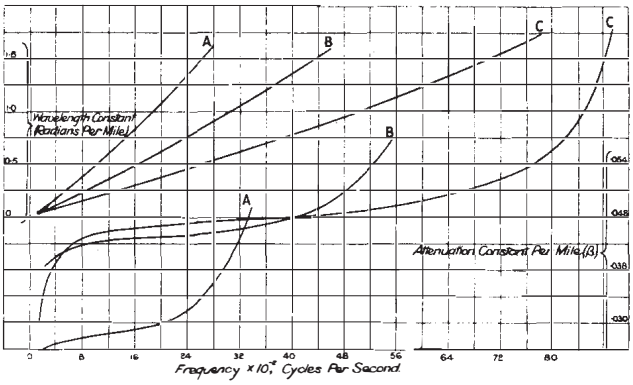


FIG. 27.—TYPICAL ATTENUATION AND WAVE-LENGTH CHARACTERISTICS FOR MODERN COIL-LOADED REPEATER SECTIONS OF CABLE.

A—25 lb. conductor, 120 mH at 2000 yds.
B— ,, ,, 44 mH ,, ,,
C—40 lb. ,, 15·5 mH ,, ,,

From equation (8) and Fig. **26** it will be seen that there are π *coils per wave-length at the cut-off frequency*. (See Section 7, pp. I., on coil-loaded lines).

Note 2.—By considering the foregoing Sections 8 and 9, it will be seen that a coil-loaded line must *terminate in a half-value loading coil* (or *half* loading-coil *section length*) for smooth propagation, *i.e.*, for absence of reflections, etc.

Note 3.—The influence of the spacing of the coils in the cut-off frequency can be seen from equation 5 and the following example :—

Example 1. — Calculate the approximate theoretical cut-off frequencies for a circuit having C = 0.065 μF per mile and loaded with :—

(1) 15.5 millihenries at 2000 yds. spacing.
(2) 44 mH. at 2000 yds. spacing.
(3) 120 mH. at 2000 yds. spacing.

The cut-off frequency $f_c \fallingdotseq \frac{1}{\pi d \sqrt{CL}}$,

equation (5).

$\therefore$ For the 15.5 mH. case $f_c = \frac{1}{\pi \sqrt{15.5 \times .074}}$

$\fallingdotseq$ 9,700 p.p.s.

Similarly for the 44 mH.,

$f_c \fallingdotseq$ 5,700 p.p.s.

For the 120 mH.,

$f_c \fallingdotseq$ 3,000 p.p.s.

In connection with this example, See Fig. **27**, which shows some actual measured attenuation-frequency curves for circuits loaded as in the above example. Note the close agreement of actual with calculated cut-off frequencies. The larger conductor (40 lb.) in the case of curve C accounts for its attenuation over the frequency range 400-4000 p.p.s. being *nearly the same as that for the curve B,—a heavier loaded circuit* which has 20 lb. conductor—the lower resistance in the case of C keeping the attenuation of C down to that of B.

Example 2.—A cable has the following constants:—

R = 88, C = 0.054, L = 0.001, G = 5×10^{-6}. What inductance per mile must be added to make the circuit distortionless? If coils of 175 millihenries be used, what spacing will be necessary? Calculate transmission equivalents per mile of the cable before and after loading. Neglect resistance of loading coils. [*C. and G., 1931*].

Assuming R is in ohms, C in μF, L in Henrys and G in mhos per mile loop, then, from the formula in Section 3, LG = CR, the required inductance $\fallingdotseq \frac{0.054 \times 88}{10^6 \times 5 \times 10^{-6}}$ H per mile loop.

From this *consideration only* the spacing is $\fallingdotseq$ 324 yds.

The transmission equivalents will be given in Section 10 of these notes.

Useful References for Sections 7 to 9:—

"Transmission Circuits for Telephonic Communication," by K. S. Johnson. Published by the Library Press, Ltd., London.
"Telephonic Transmission," by J. G. Hill, (Chapter IX.). Published by Longmans, Green & Co., Ltd.
"Telephone Transmission," by J. E. Statters. I.P.O.E.E. Paper 101.
"Attenuation of Coil Loaded Lines," by H. F. Mayer. T.F.T., Part 6, 1927.

SECTION 10.

Elementary Considerations of the Transmission Efficiency of Telephone Circuits. — Transmission Units Used.

It is of little use to have a telephone system over which a large volume of sound is transmitted unless the quality of the received sound is of such a standard as to render the reproduction easily intelligible; and equally undesirable to have a system which has a very high standard of reproduction but so little received volume as to render it almost unintelligible. It therefore becomes necessary to provide means for measuring and comparing *both volume and quality* of received sounds when dealing with parts (terminal apparatus, intermediate apparatus, connecting lines, etc.), or the whole of a complete transmission system. To this end certain standard reference systems have been devised and the European Master Reference System, situated in Paris, (which is a replica of the Master Reference Standard used in America) represents the present stage in the development of an absolute international standard—(See Section 11 of Notes).

There are thus two main factors which determine the **intelligibility** of a telephone system (*i.e.*, its overall efficiency for transmission of the meaning of ordinary speech sounds used for conversation), viz.:—

(1) *Volume efficiency* which determines the ratio of acoustic power, or volume, of the sounds received over the system to the sent power.
(2) *Articulation efficiency* which determines the quality or faithfulness of reproduction of the transmitted sounds.

In addition to the influence of the above two factors, upon the intelligibility of the system there will be

(3) *Cross-Talk* and over-hearing—*i.e.*, interference from neighbouring telephone circuits.

(4) *Cross-fire, i.e.*, interference from telegraph circuits.

(5) *Noise* extraneous to the terminal apparatus, *i.e.*, room noises, etc.

(6) *Noise* in the circuit itself, *i.e.*, bad joints, microphonic "frying" noises, etc.

(7) *Power-Circuit* interference, *i.e.*, principally the influence of the higher harmonics of an A.C. power-supply frequency and of the ripple in the case of D.C. supplies.

A brief consideration of these factors and the units concerned follows:—

(Section 10 to be continued.)

A SUGGESTION TO EXTEND FACILITIES IN RESIDENTIAL AREAS.

12, Lothian Road,
Stockwell,
S.W.9.
April 21, 1931.

The Managing Editor,
P.O.E.E. Journal,
Alder House, E.C.1.

Dear Sir,

Enclosed please find a scheme by which the telephone system of this country could be extended. If you deem it worthy of publication in the *P.O.E.E. Journal*, to which I subscribe, I should be greatly obliged.

Yours faithfully,
A. L. MARRIOTT,
Youth in Training,
Brixton External.

SCHEME FOR THE PROVISION AND EXTENSION OF TELEPHONES IN RESIDENTIAL AREAS.

Houses or flats in the course of construction under Local or National building schemes that could be classified as Telephone property.

(*a*) The builders or governmental authorities responsible for the building be approached and arrangements made for the payments of the hire charges as outlined below, and also for the installation of plant.

(*b*) That where the houses are intended for sale by monthly or quarterly payments off a mortgage, the deposit and quarterly hire charges be included in the repayments of mortgage made by the tenant-subscriber to the firm or local authority holding the mortgage.

(*c*) The cost of the calls made by the subscriber to be invoiced to him in the usual manner.

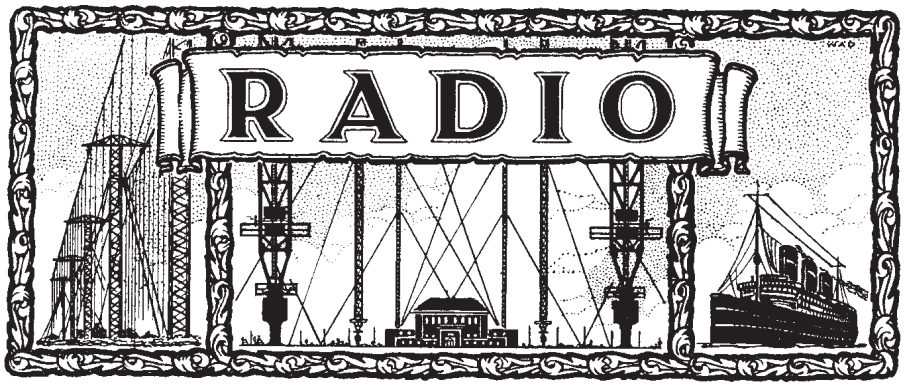
(*d*) In the case of houses or flats intended for weekly rental the deposit and quarterly charges be added to the rent in the form of weekly payments. The cost of the calls per quarter to be credited to the subscriber in the usual way. The quarterly hire charges to be collected from the owners of the property.

(*e*) In the advent of a house or houses qualifying for a government subsidy, a liaison could be established with the Ministry of Health for the purpose of ensuring that the applicants for the subsidy would be willing to allow the G.P.O. to instal plant in the property.

Summary and Advantages.

It would enormously increase the demand for telephones in residential areas.

The chief bar to the extension of the system in residential areas is due to the deposit and quarterly hire charges. With the removal of this bar, the extension of the system would be greatly facilitated.



DEVELOPMENTS IN THE USE OF VERY SHORT RADIO WAVES.

ABOUT the year 1924 it began to transpire that short radio waves, that is to say, waves below 50 metres in length, had unsuspected propagation properties and that by their use it was possible to obtain communication over long distances with powers which would be hopelessly inadequate with longer waves. As a result of this discovery, great activity was manifested all over the world in opening short-wave services for long distance communication. It soon became evident that for long distance work the lower useful limit of wave-length was about 12 metres and that for waves shorter than this the range was extremely restricted. In the light of our present knowledge, we know that this is due to the fact that waves of between 12 and 50 metres length are reflected efficiently by the medium in the upper regions of the atmosphere, and by repeated reflections are projected for great distances. Waves below about 10 metres in length are not reflected and in consequence their range is limited to that of the direct ray. The range is short because obstructions in the path of the ray, including the earth itself, readily absorb the energy in the wave.

As a result, it is generally desirable, if not essential, that there should be a clear and unobstructed path between the transmitter and the receiver for these very short waves. That is to say, they require a clear optical path and in many ways the characteristics of these waves resemble light waves. Directive transmission is readily achieved, either by means of metallic reflectors or by small antenna array systems, both of which can be made extremely effective on these wave-lengths. The fact that the radius of action of these waves is definitely limited suggests a number of useful applications for them. For example, one of the disadvantages of broadcast waves between 200 and 500 metres is that they cause disturbance over distances much greater than their useful range. For broadcast relay stations the very short waves of the order of, say, 5 to 10 metres seem particularly suitable. They are also suitable for low power short range services, such as between islands and the mainland, or across narrow estuaries or channels.

The simplest way of producing these short waves is by means of a spark discharge, as was used by Hertz in his classical experiments, which were conducted with waves of this order. Owing to its disturbing effects the use of spark apparatus is forbidden by international convention. It is possible to generate waves between 12 metres and 1 metre in length by ordinary three-electrode valves having coupled grid and anode circuits, as are used to generate longer waves. For the generation of waves shorter than about 1 metre in length, other arrangements are necessary, as the dimensions of the internal structure of the valve play an important part in determining the wave-length generated. There are two well-known types of valve oscillations capable of generating these waves, known as the Barkhausen-Kurz oscillations and the Gill-

Morrell oscillations. In each system, the grid of the valve has a positive potential in respect to the filament, while the anode is at zero or at a negative potential in respect to the filament. Oscillations are set up by electrons in the inter-electrode space, either between the plate and the cathode, or between the grid and the plate. The frequency of the Barkhausen-Kurz oscillations is determined solely by the electrode dimensions and the applied potentials, while the frequency of the Gill-Morrell oscillations are determined exclusively by the circuits connected to the valve and not by the electrode potentials.

General Ferrié has now appeared in the " Annales des Postes " of April, 1931.

Using waves of 17 cms. in conjunction with circular mirrors of 120 cms. aperture, telegraph communication has been obtained up to 37 km., and using small cylindric parabolic mirrors of 60 cms. aperture, telephone communication has been obtained up to $7\frac{1}{2}$ km.

The Laboratoires Standard, Paris, have recently used waves of 16 cms. in an experimental radio telephone circuit between Dover and Calais, and a demonstration of the working of this system was given on 31st March, 1931,

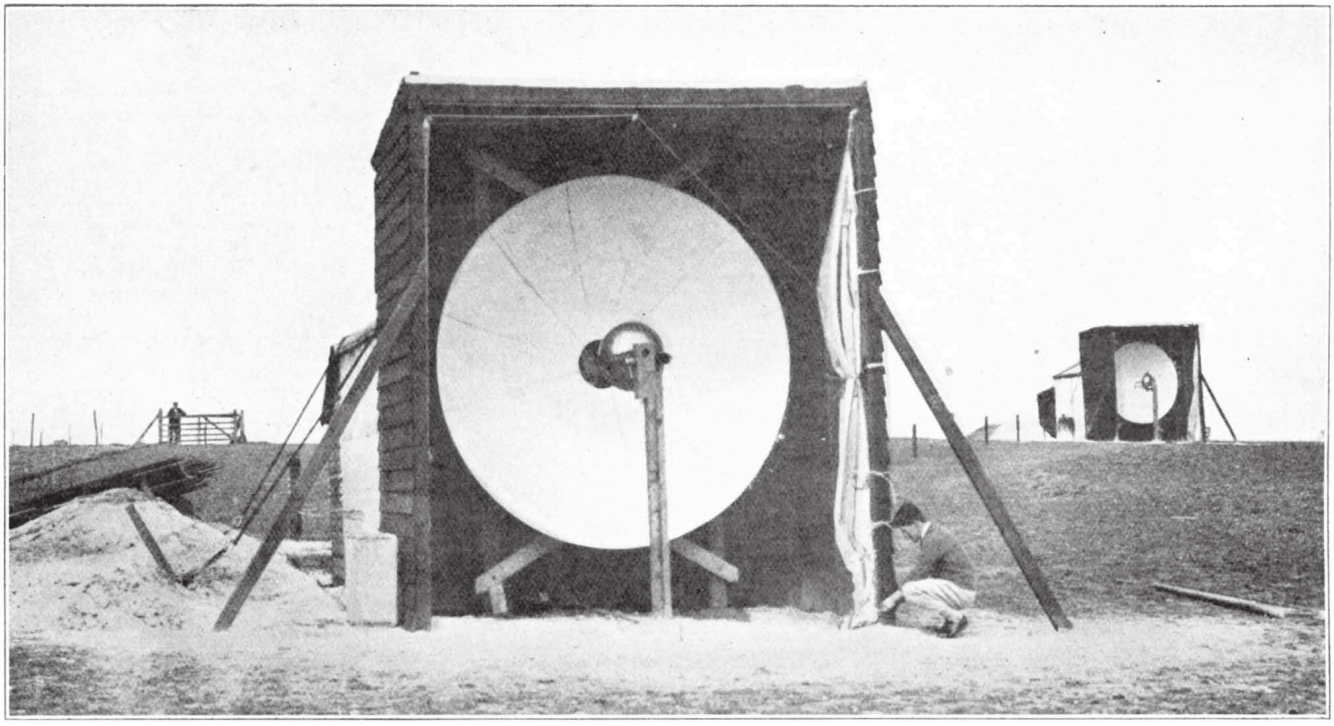


Fig. 1.—Transmitter and Receiver at Dover.

The lower limit of wave-lengths of these oscillations appears to be of the order of 12 cms. Research work on the practical utilisation of these short waves for transmission has been carried out by a number of experimenters, notably Uda in Japan, and Pierret, Beauvais and Gutton in France. Uda used waves of about 50 cm. and obtained telegraphic communication up to 39 km. Particulars of the French experiments have been published from time to time and an interesting summary of this work by

to a large and influential audience, including prominent representatives from Government services and the press. The installation consists of a transmitter and receiver at each place so that two-way conversation is possible.

Fig. 1 shows the transmitting and receiving installations, while Fig. 2 shows a more detailed view of the transmitter. The transmitting and receiving valves are each situated near the focus of a paraboloid mirror of about 200 cms. aperture, a small antenna external to the valve being

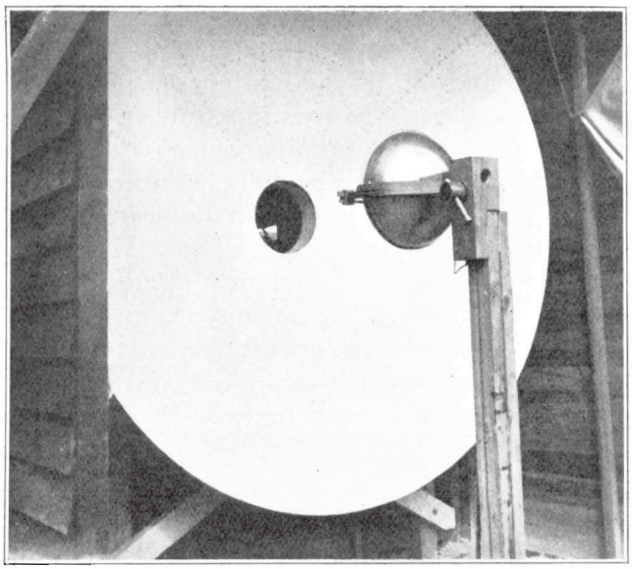


FIG. 2.—CLOSE-UP VIEW OF THE DOVER TRANSMITTER.

The micro-radion is housed in the small casing seen in foreground. Immediately in front of it is the one inch aerial.

FIG. 3.—INTERESTED SPECTATORS.

Col. Sir T. F. Purves, Capt. Davies (Mayor of Deal), Mr. L. Simon (Director of Telegraphs and Telephones). Left background, Mr. G. F. Greenham.

arranged at the focal point. In order to prevent unreflected divergent radiation from the antenna, a small semi-hemispherical mirror is placed outside the antenna so that all forward radiation from the antenna is reflected back to the paraboloid reflector. Due to the use of mirrors at each end a gain of 52 decibels is obtained; this represents a gain of 26 decibels at each mirror, which is as high as that obtained with a high efficiency antenna array on waves of about 16 metres.

The actual details of the valve used for this circuit have not yet been published. The quality of transmission obtained over this circuit is excellent and suggests that a wide field of usefulness is open to development, particularly for cross-channel services of this kind.

Very little information is yet available as to the frequency spacing necessary between services located near each other but, presuming that this is not abnormal, the number of channels available on these wave-lengths is stupendous. Assuming a frequency spacing of 100 kilocycles between services, on wave-lengths between 16 cms. and 1 metre it would be possible to operate contiguously 15,000 channels. If a frequency spacing of 1000 kilocycles is found to be necessary, we should still have 1500 channels available. Even at the present rate of growth this would provide all the cross-channel circuits for many years to come.

BIBLIOGRAPHY.

Hollman. " *Electron Oscillations in a Triode.*" *Proc. I.R.E., February, 1929.*

Uda. " *Radiotelegraphy and Radiotelephony on half metre waves.*" *Proc. I.R.E., June, 1930.*

Ferrié. " *Radiotelegraph and Radiotelephone Transmission with very Short Waves.*" " *Annales des Postes,*" *April, 1931.*

The first and third of the above mentioned papers contain comprehensive bibliographies.

FREQUENCY MEASUREMENT IN THE BRITISH POST OFFICE.

F. E. Nancarrow, A.R.C.Sc., A.M.I.E.E.

P.O. FREQUENCY STANDARDS.—In the Radio Department of the British Post Office, all frequencies are measured by reference to the harmonic frequencies of a tuning-fork maintained in the Radio Laboratories at Dollis Hill, London. This fork can be regarded as the Post Office standard of frequency and it is arranged that the frequency of vibration of the fork can be checked at any time by comparison with unit time as obtained directly from the Greenwich Observatory.

Fork and Temperature Control.—The fork is of elinvar of the type now generally known and is used for driving a multivibrator equipment. In the Post Office equipment, the fork and its associated driving valve are contained in a small unit which is separated from the main multivibrator apparatus. This unit is contained within the inner space of a double oven, each space of which is thermostatically controlled. The outside dimensions of this oven are 3 feet × 3 feet × 3 feet, and the inner oven is mounted symmetrically within the space of the outer, with an air space of 6 inches between the inner walls of the outer and the outer walls of the inner oven. The actual fork equipment is mounted symmetically within the inner space of the inner oven. The construction of the ovens follows recognised lines, the ovens being made up of layers of heat-insulating and heat-distributing materials. A photographic view of the interior of the ovens is given in Fig. 1.

The temperature of the outer oven is maintained at about 25°C. by means of a bi-metallic strip thermostat. The heaters for this oven are distributed over four of the faces of the inner heat-distributing layer and the thermostat is mounted on one of these faces. The heaters of the inner oven are distributed over four of the outer faces of the inner heat-distributing layer and the thermostat is also mounted on one of these faces. This thermostat is that associated with a Cambridge Instrument Co.'s Recording Thermostat (See Fig. 2) and the control is such that the heat cycle is of the order of eight seconds and the temperature variation of the heat-distributing layer is not greater than ± .05°C. Under these conditions it can be presumed that the actual temperature variation of the fork is not greater than ± .01°C. and, since the temperature coefficient of the fork is + 5 parts in 10^6 per 1°C. rise in temperature, it can be safely assumed that the change in frequency of the fork on account of temperature is never greater than 5 parts in 10^8.

The temperature of the inner oven in which the fork is contained is maintained at about 30°C., this temperature being chosen to ensure that the fork is always above the summer temperature of the room in which the oven is kept. At this temperature the fork vibrates at 1000.000 cycles per second and the temperature of the inner oven was critically adjusted to procure this result.

Pressure Effect.—The extent to which changes in pressure contribute to the variation in frequency of the fork are under investigation and at the present time the fork is not sealed against the effect of pressure changes. In any case, the fork is maintained under conditions whereby frequent comparisons with unit time are made and hence any change due to pressure accounted for.

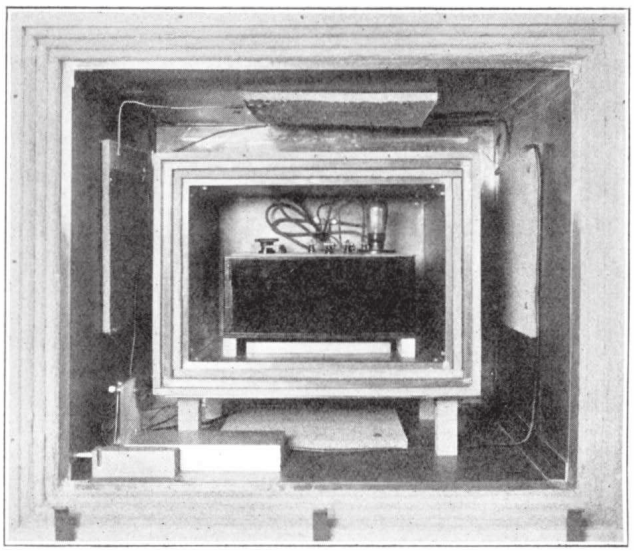


Fig. 1.—Double Oven.

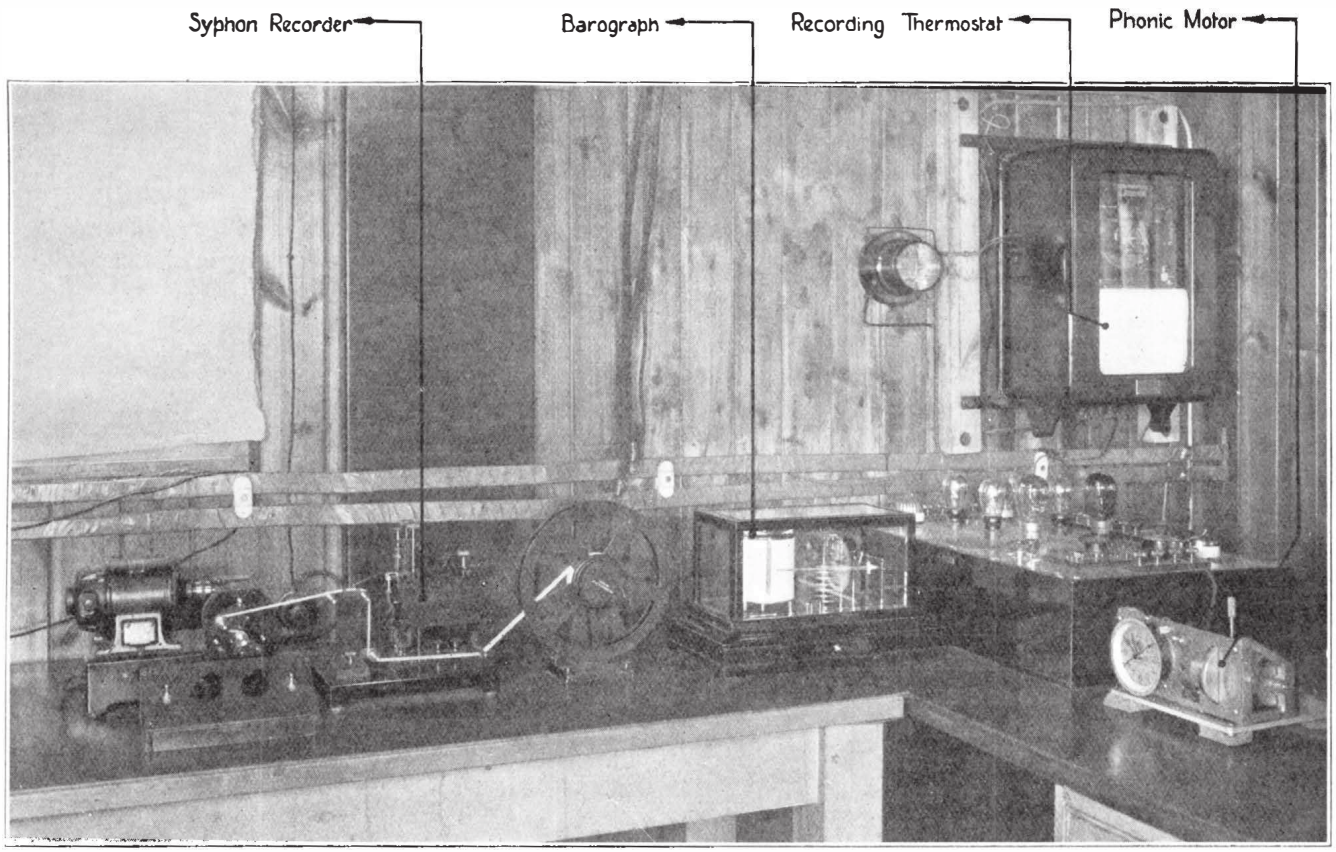


FIG. 2.—TIMING GEAR, ETC.

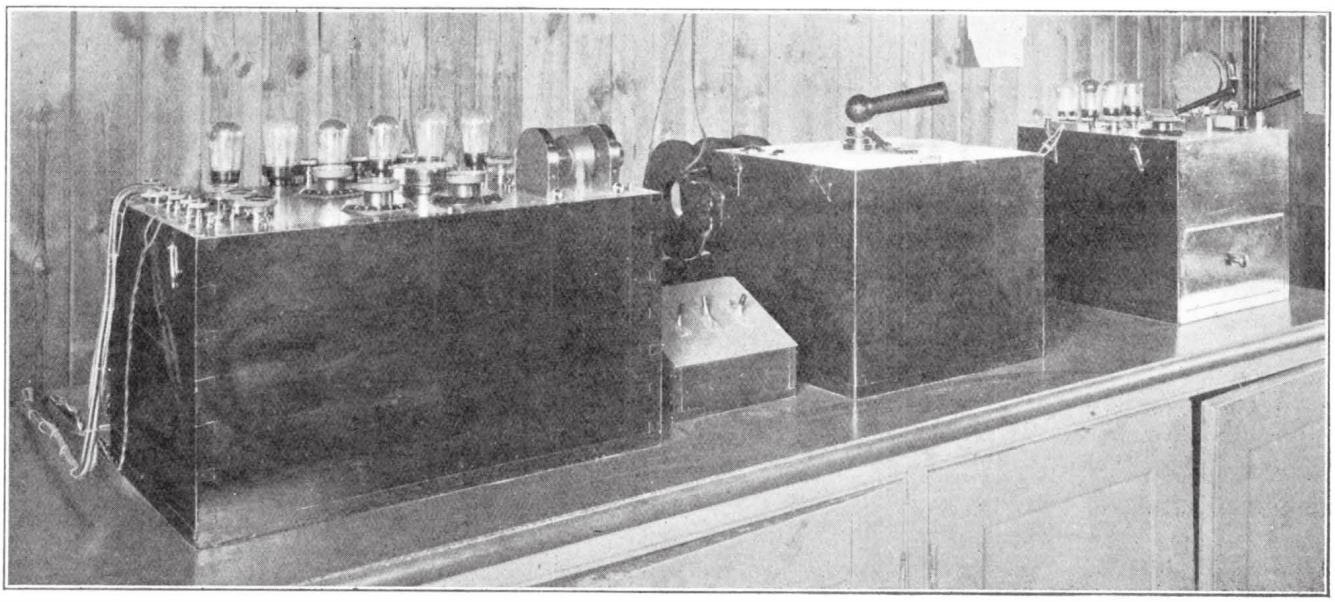


FIG. 3.—MULTIVIBRATOR.

Effect of load on Frequency.—An intermediate circuit is interposed between the fork circuit and the multivibrator to minimise any possible effect upon the frequency of the driving circuit due to the reaction of the load. The multivibrator equipment is shown in Fig. **3.**

Determination of Absolute Frequency of Fork.—The method adopted in obtaining a comparison with unit time depends firstly upon utilising an output from the intermediate circuit following the tuning fork and, after amplification, causing this to drive a phonic motor. The particular phonic motor used is constructed by General Radio Co. and is designed to reduce hunting to a minimum. It is equipped with a cam which makes contact every second, provided that the frequency of the controlling source is precisely 1000 cycles per second. The motor is also geared to a clock which, at this frequency of control, is arranged to record accurate time.

The contacts which are operated by the cam are in circuit with one of the coils of a double coiled syphon recorder, so that a record is made on the tape each time the cam closes the contacts. The other coil of the syphon recorder is energised either from the current impulses received hourly from the Greenwich Observatory, or by the time signals emitted from the Rugby Radio Station. These latter signals, which are sent out at 1000 GMT and 1800 GMT respectively and maintain a time interval seldom in error by more than .01 second, allow of a long period check of the frequency of the fork, whilst the hourly signals allow of a shorter period and, incidentally, because of the slightly less reliable time interval, slightly less reliable comparison with the unit time.

Fig. **2** shows the lay-out of the phonic motor and amplifier, the Cambridge Instrument Co.'s Recording Thermostat, Barograph and Syphon Recorder.

The velocity of the tape of the syphon recorder is such that the second marks from the phonic motor are separated about three inches, and the error in measuring the displacement of the two records, *i.e.*, the record from the phonic motor and that derived from the time signals, does not exceed .02 inches. The error in frequency estimation due to this cause should therefore not exceed .0066 parts in 28,800 when operating on the long period comparison, *i.e.*, 0.23 parts in 10^6. The error due to the possible deviation of the signalled period from exactly 28,800 seconds, *i.e.*, .01 second, gives rise to a frequency error of 0.35 parts in 10^6 and hence the total maximum error in this method of comparison is of the order of 0.58 parts in 10^6. With a shorter interval for comparison, the error due to these causes is of course correspondingly increased.

These estimations take no account of possible frequency changes due to pressure, but as stated previously, the effect of pressure in this connection is under investigation.

Application to Measurements.—The standard fork maintained as previously described is caused to control the multivibrator equipment of fundamental frequency 1000 cycles per second and 20,000 cycles per second in the manner described by Dr. D. W. Dye in the Philosophical Transactions of the Royal Society Series A, Vol. 224.

Equipment is maintained in the Radio Laboratory in intimate association with this apparatus for receiving signals of frequencies over the commercially worked range, and for relating these frequencies to the harmonic frequencies of the tuning fork.

Measurement of Low and Medium Radio Frequencies.—The method relies upon the utilisation of two beating or heterodyne oscillators used in connection with a receiver. One of these oscillators, called the beating oscillator, is of the type which would be normally used with such a receiver, whilst the other, termed the comparison oscillator, is of special construction in that it is designed to maintain constant frequency with variation in load, H.T. or L.T. supplies, and its oscillating circuit is arranged to have maximum capacity. This capacity is made up of two parts, one much smaller in value than the other; the smaller capacity has the form of a specially designed variable condenser having a very large and finely divided scale, whose capacity change is proportional to change in scale reading.

The operation of measurement of frequency of an incoming signal is as follows. The signal is received in the normal manner, using the beating oscillator, and the comparison oscillator adjusted to exact synchronism with the incoming signal by the well-known method of double beating. The reading of the scale of the variable condenser on the comparison oscillator is noted, and from the multivibrator apparatus consecutive harmonics are selected, such that their frequencies synchronise with frequencies of the comparison oscillator corresponding to settings of the variable condenser lying respectively

above and below the reading obtained for synchronism with the incoming signal. The frequency of the incoming signal can then be obtained by interpolation between the three readings of the condenser, since the frequencies corresponding to the selected harmonics are known.

Normally, true harmonics of the tuning fork are utilised for the interpolation, *i.e.*, the interpolation is carried out within a frequency space of 1000 cycles per second, but if greater accuracy is required this interval can be reduced to any convenient integral fraction of this frequency interval.

Measurement of Medium High and High Radio Frequencies.—The method employed for the measurement of Medium High and High Frequencies is similar in principle to that already described, inasmuch as it relies upon the adjustment of an interpolating condenser to synchronise an oscillator with the incoming signal and with harmonics of a source whose fundamental frequency is a known multiple of the tuning-fork frequency.

In this system the output from either the Low or High Frequency Multivibrator is passed through an amplifier, the output of which is caused to control the frequency of an oscillator which will be termed the reference oscillator. By this means the reference oscillator can be caused to oscillate at any harmonic frequency up to the three hundredth of the Low Frequency Multivibrator and it is calibrated at various of these harmonic frequencies. The harmonics of this reference oscillator are used as reference points when measuring the frequency of an incoming signal, as described below. The reference oscillator, as used for the measurement of high frequencies, is thus analogous to the Low Frequency Multivibrator as used for the measurement of low frequencies.

Another oscillator, termed the comparison oscillator, with whose tuning circuit is associated the special interpolating condenser, is used to obtain the actual signal frequency measurement. The oscillator is synchronised alternately with the signal and with two harmonic frequencies of the reference oscillator situated on either side of the signal frequency and the required frequency obtained by interpolation.

Thus it is possible to synchronise the reference oscillator to such an order of harmonic, say the nth, of the Low Frequency Multivibrator that the mth harmonic for the oscillator is less than m kc/sec: (assuming the tuning fork frequency is 1 kc/sec) removed from the frequency to be measured. If now the reference oscillator be synchronised with the $(n \pm 1)$th harmonic (the sign being dependent upon whether the frequency to be measured was above or below the harmonic frequency already dealt with) then the mth harmonic of the reference oscillator at

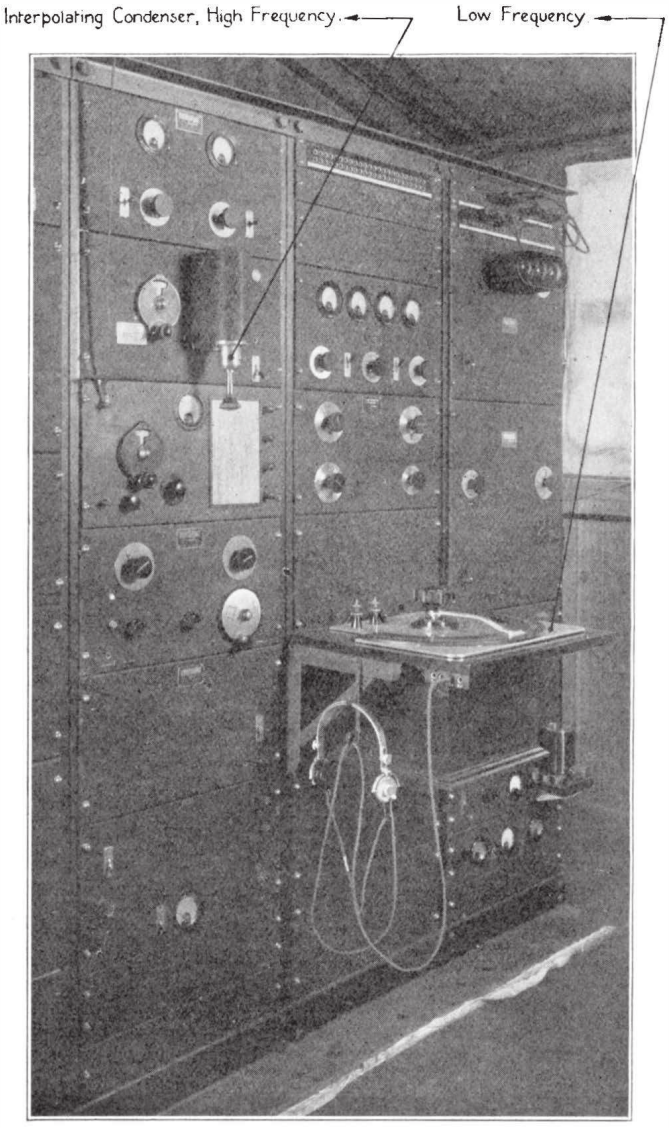


FIG. 4.—RECEIVING AND MEASURING APPARATUS.

this fundamental frequency will give the second interpolation point, from which the incoming signal frequency can be obtained.

If in the above description, n is assumed to be 300 and a frequency of the order of 15,000 kc/sec is to be measured, the harmonic number m would be of the order of 50 and hence the interpolation interval 50 kc/sec.

The comparison oscillator in association with the short-wave receiver used for obtaining the signal can be set to absolute synchronism with the signal and also to synchronism with the two frequencies of the reference oscillator, which are spaced 50 kc/sec apart, and which are arranged to lie on either side of the signal frequency. The signal frequency is then obtained by interpolation from the three readings of the interpolating condenser of the comparison oscillator. This condenser is of special design and consists essentially of a cylindrical plunger moving inside a hollow cylinder, the motion being controlled by a micrometer screw. The total variation in capacity is of the order of 12 μF and there is linear relation between scale reading and capacity change.

For more precise measurements than can be obtained as described above, it is arranged that the reference oscillator is set such that the harmonic combination nm kc/sec is less than, say, 10 kc/sec from the frequency to be measured. The comparison oscillator setting is synchronised with this harmonic frequency of the reference oscillator and then successively with frequencies differing in steps of 1 kc/sec from this frequency until the setting corresponding to synchronism with the signal frequency is overlapped. In this manner the comparison oscillator can be set to two frequencies differing by 1 kc/sec, which are on either side of the signal frequency, and hence the interpolation interval reduced to 1 kc/sec.

The above procedure is that usually followed when it is required to follow small changes in frequency of a transmitter or when a very high degree of accuracy is required. With an unknown station it requires a preliminary measurement of the frequency by the method first described, but once measurement has been made checks can be made very rapidly and with an extremely high order of accuracy.

Allowing for the possible errors in the standard as previously described, and using the 1 kc/sec interval method of measurement, it is considered that the maximum error in making frequency measurements on the medium high, and high frequency ranges should not exceed $\pm$ 3 parts in 10^6.

The whole of the receiving equipment and the various oscillators as described are mounted in rack form and are shown in Fig. **4**.

FREQUENCY CONTROL EQUIPMENT OF POST OFFICE SHORT-WAVE TRANSMITTERS.

E. J. C. Dixon, A.C.G.I., B.Sc., D.I.C.

1.

Introduction. — The first short-wave transmitters constructed by the Post Office consisted of self-oscillating single valve circuits, employing glass envelope valves of about 1500 watts dissipation, and the frequencies on which the transmitters operated were checked by means of simple wavemeters of the absorption type. The frequency constancy was often little better than plus or minus 2000 parts in a million, due to variations in the supplies to the oscillator, variations in the internal characteristics of the valves, changes in the values of the circuit components due to heating and changes in the antenna load with varying conditions of wind and weather. As the advantages of the short-wave channels became more apparent and more stations sought to transmit on frequencies in the commercial range, *i.e.*, 3,000 to 30,000 kilocycles per second, it soon became necessary to restrict the variation of frequency of transmitters using this band. A demand for some method of fre-

quency control of telephony transmitters also arose, owing to the peculiar phenomena associated with the transmission of modulated carriers at the high frequencies employed.

The method in use for the frequency control of long-wave transmitters was the selection of harmonics from a valve-maintained tuning-fork oscillating at a frequency of the order of 1500 cycles per second, and in order to extend this equipment to the very high frequencies it would have been necessary to instal a large number of harmonic selecting, filter and amplifying stages. A method of frequency control was therefore developed in which the constant frequency source was a piezo-electric crystal plate oscillating at a frequency of the order of 1500 kilocycles per second. The frequency was raised to that of the required carrier, usually from 5,000 kc/sec to 20,000 kc/sec, by means of two or three frequency-doubler stages and the power level was then raised to ten kilowatts by means of amplifying stages at the carrier frequency. The present article describes typical equipment designed for frequency control of a high order of accuracy and is illustrated by photographs of the apparatus recently installed for the telegraph transmitter GBM at Oxford Radio Station.

The Quartz Oscillator.—The brothers Curie, investigating piezo-electric substances in 1880, showed that all non-conducting hemihedral crystals became electrically polarised when caused to contract and became polarised in the opposite sense when caused to expand. Owing to its mechanical strength and chemical stability, quartz is the most useful of the natural piezo-electric substances and, since 1922, when Cady developed quartz resonators and oscillators for frequency standardisation, the use of quartz plates and bars for frequency standards has greatly increased. The Post Office made use of quartz resonators in 1925 in connection with frequency standardisation and in an article by F. E. Nancarrow* it was stated that an oscillator could be set to the resonant frequency of a quartz rod with an accuracy of the order of 1 part in 50,000, which was much greater than the accuracy with which the frequency of the oscillator itself could be measured. It is interesting to note that the accuracy of frequency measurement using the Multivibrator apparatus was 100 parts in a million at that date, whereas at the present time the accuracy of measurement using similar apparatus with refinements and the provision of a method of referring the frequency standard to G.M.T. is of the order of 5 parts in a million, while the accuracy of transmitters themselves can be made considerably better than 100 parts in a million. The quartz oscillator is a thermionic valve circuit in which a quartz resonator is used as an oscillatory circuit of low decrement, in such a way that the frequency of oscillation of the circuit is mainly dependent on the dimensions of the quartz plate. There are several circuits which may be used and the one used by the Post Office has a tuned-anode circuit and a quartz crystal connected between grid and filament. Fig. 1*a* shows the original circuit, in which a 50 watt valve having an anode voltage of the order of 800 was used, and Fig. 1*b* shows

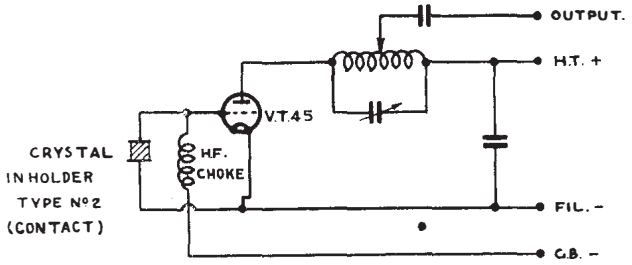


FIG. 1*a*.

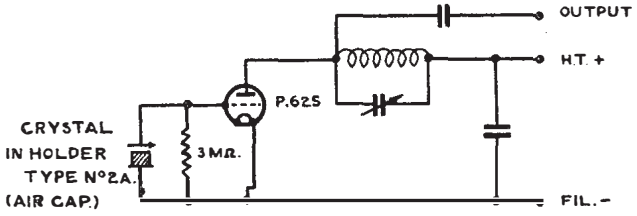


FIG. 1*b*.—CRYSTAL OSCILLATOR CIRCUIT.

the circuit in use at present with a P625 valve and an anode voltage not exceeding 120. In reducing the power of the oscillator, two advantages were gained, viz., (*a*) the heating of the crystal due to the high frequency current through it was reduced and therefore the variation due to the crystal temperature coefficient was reduced and (*b*) it became possible to use an air-gap type holder which reduced variations due to the upper

* *Journal P.O.E.E., Vol. 18, Part 2, July, 1925.*

contact electrode and provided a vernier adjustment of frequency which is extremely useful.

The method of cutting the quartz crystal plate may be understood by reference to Fig. 2, which

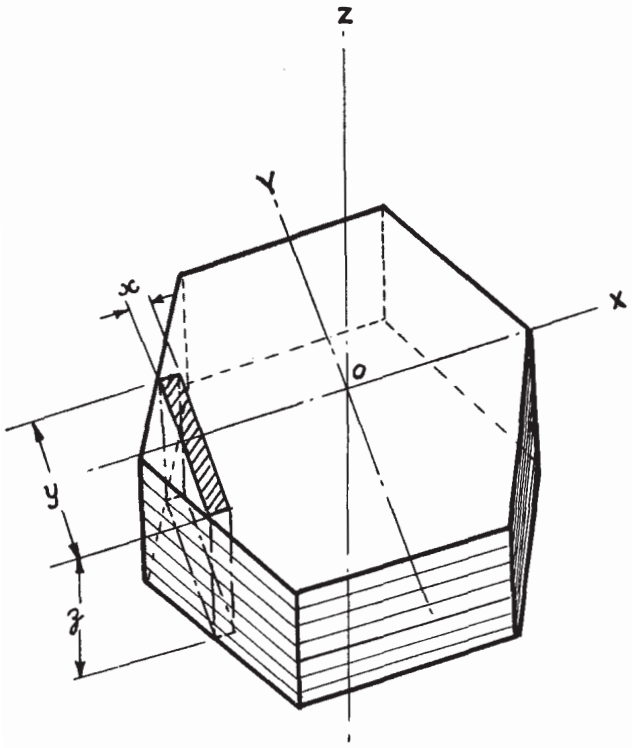


FIG. 2.—SECTION OF QUARTZ CRYSTAL.

represents a section about an inch in thickness cut parallel to the lines of crystal growth, which may be seen on the faces of the crystal. The area of cross-section is seldom a perfect hexagon, but the angles between the faces are always 120 degrees. OZ represents the trigonal axis, usually referred to as the optical axis, and OX represents one of the three diagonal axes, usually called the electric axes, which are parallel to the faces of the crystal. OY is one of the third or "mechanical" axes and is at right angles to OZ and OX.* The quartz plates are cut perpendicular to an electric axis as shown in Fig. 2, in which case they are known as "X cut plates" or perpendicular to a mechanical axis, in which case they are called "Y cut plates." Owing to the fact that the Modulus of Elasticity is not the same in all directions through the crystal, the properties of X and Y cut plates are different. There are two quantities which are of importance —(*a*) the relation between the thickness (*x* in the case of the X cut crystal shown in Fig. 2) and the frequency of response of the plate, and (*b*) the temperature coefficient of frequency. The former quantity, which may be called the "thickness coefficient," is usually expressed in kilocycles per second per millimetre and the temperature coefficient of frequency is expressed in parts per million per degree Centigrade. The differences between X and Y cut plates may be summarised as under:—

	X cut.	*Y cut.*
Thickness Coefficient ...	2.7	2.0 kc/sec/mm.
Temperature Coefficient ...	−25	+70 parts/10^6/°C.

These are average values, since the modulus of elasticity appears to vary from specimen to specimen of quartz crystal, and the value of temperature coefficient is complicated by the fact that it is almost impossible to cause a quartz plate to oscillate in a single mode, *i.e.*, components of other modes of oscillation than the thickness vibration are always present. The trigonal symmetry of quartz and the fact that the modulus of elasticity varies with direction thus give rise to considerable difficulties in the practical working of a quartz plate, and in practice it is found that the X cut usually presents less difficulties due to unwanted modes of oscillation. This property, coupled with the fact that the temperature coefficient is invariably smaller than with the Y cut, has led to the adoption of X cut crystals in Post Office practice.

The procedure in producing a quartz plate is as follows:—A section as shown in Fig. 2 is cut parallel to the lines of crystal growth and the section is examined optically, using light passed through crossed Nicol prisms, to detect flaws or twinning. If satisfactory, the section is marked with an electric axis by scribing a line parallel to a face. Lines perpendicular to the electric axis, separated by a thickness somewhat greater than that required for the finished plate, are then set out and the section is sliced along them by means of a lapidary's saw or wheel. Several plates of the same length (*y*) are usually cut of

* *Note.—The "third" axes are not axes of symmetry in α or low quartz, but become axes of symmetry when the quartz is heated above 570°C and is no longer piezo-electric.*

the same thickness and worked in a gang grinding machine so that the faces are accurately parallel. They are then tested for piezo electric response in a test circuit and adjusted by hand grinding until the correct frequency is given. Sometimes it is necessary to reduce the length y or the length z so that harmonics of oscillations corresponding to these lengths do not interfere with the required thickness vibration and, owing to the complicated nature of the responses, there are often discontinuities in the oscillations obtained as the thickness of the plate is progressively reduced. It is thus often necessary to prepare several plates in order to get one completely satisfactory specimen, especially when a high order of accuracy is required.

It has been shown by Dye* that the equivalent electrical circuit of a quartz crystal is as shown in Fig. 3, in which K2 represents the

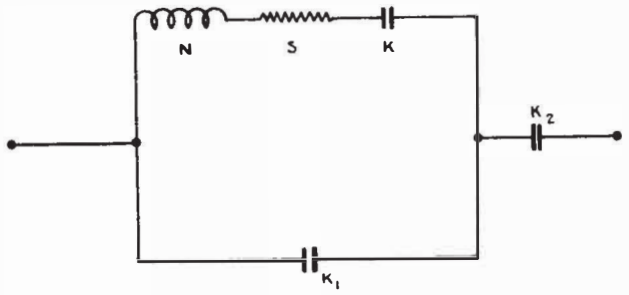


Fig. 3.—Equivalent Circuit of Quartz Crystal in Holder.

capacity of the air gap and the rest of the circuit represents the quartz crystal. The capacity K1 will, however, include the stray capacity of the holder, and the natural frequency of the whole circuit will depend on the values of K1 and K2, *i.e.*, the frequency of a given crystal will be different in holders of different capacities or of different air gaps. The equivalent circuit of the quartz oscillator is as shown in Fig. 4, in which the dotted lines represent the inter-electrode capacities and conductances. The frequency of oscillation of this circuit will not be the same as the frequency of response of the crystal as a resonator, and will depend to a small extent on the valve capacities and conductances and the tuning of the anode circuit LC. This circuit has been fully analysed by P. Vigoureux† and com-

* *Proc. Phys. Soc. Lond.* 1926, 38.

† *J. Inst. Elect. Engrs.* 1930. 18.

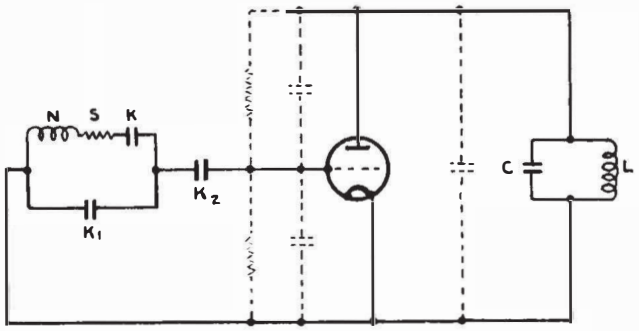


Fig. 4.—Equivalent Circuit of Quartz Oscillator.

pared with a similar circuit in which the crystal is connected between the grid and anode of the valve.

The magnitude of the variations that are likely to occur in a quartz oscillator has been found for typical crystal plates, and are as under:—

Temperature—25 parts per million per degree Centigrade.

Air trap—50 parts per million per mil air gap.

Anode Tune—30 parts per million over full range of oscillation.

Anode Voltage less than 1 part per million per 1% change.

Filament Voltage less than 1 part per million per 1% change.

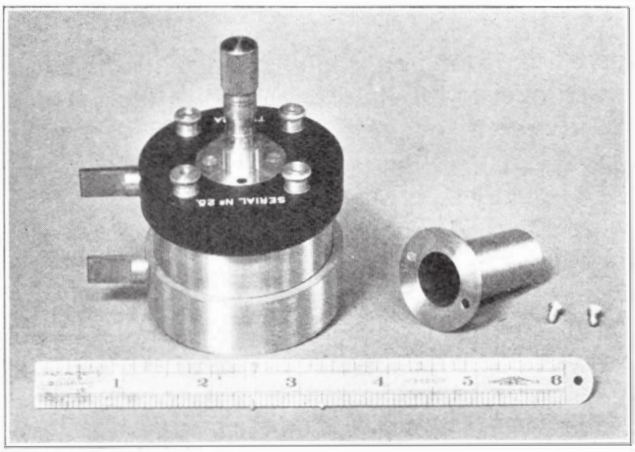


Fig. 5. Quartz Crystal Holder.

To achieve the accuracy required, the crystals and the oscillator are enclosed in a thermostat-controlled oven, thus reducing variation in temperature to a small amount and precluding the possibility of alteration of the air gap or of the anode tune, while the supply voltages are derived from the most constant source available.

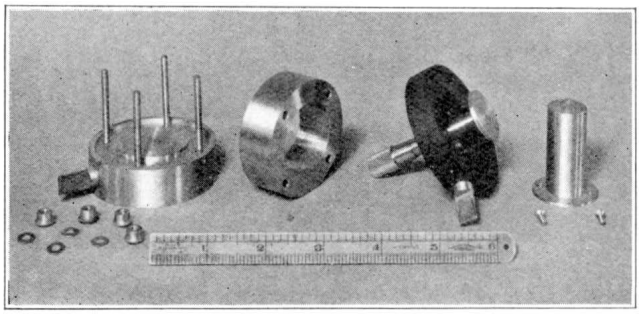


FIG. 6.—PARTS OF QUARTZ CRYSTAL HOLDER.

The temperature of the oven is usually adjusted to 50°C. and the bimetallic thermostats are capable of maintaining this value to ± 0.25°C. In testing quartz plates supplied by manufacturers a standard crystal holder is provided and the oscillators are tested with the standard circuit at 50°C. Tests of the quartz plate as a resonator are also made to check that there are no spurious " crevasses " near the required frequency.

Description of Quartz Oscillator and Oven Equipment.—The standard holder at present in use is shown assembled in Fig. **5**, while the parts are shown in Fig. **6** and consist of a lower electrode with contact blade, a metal spacer, an upper electrode support with micrometer variable electrode and contact blade, and a micrometer cover. The crystal plate, which is roughly one inch square, rests freely on the lower electrode and its movement is limited by the spacer which is just greater in diameter than the longest dimension of the crystal plate. The holder is clamped up by four nuts and the air gap may be read to 1/10,000 inch by means of the micrometer head. The cover is screwed in position when the final adjustment has been made to prevent subsequent alteration of the air gap.

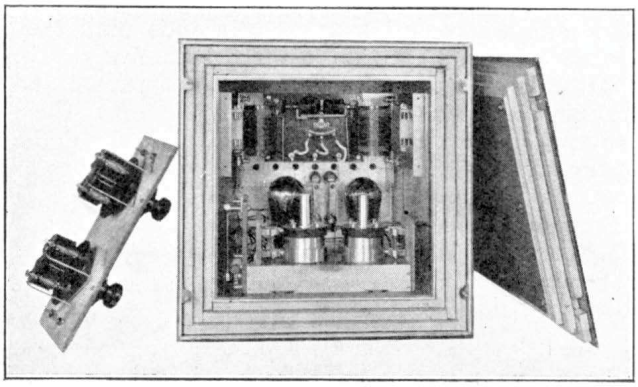


FIG. 7.—QUARTZ OSCILLATORS, THERMOSTAT AND OVEN.

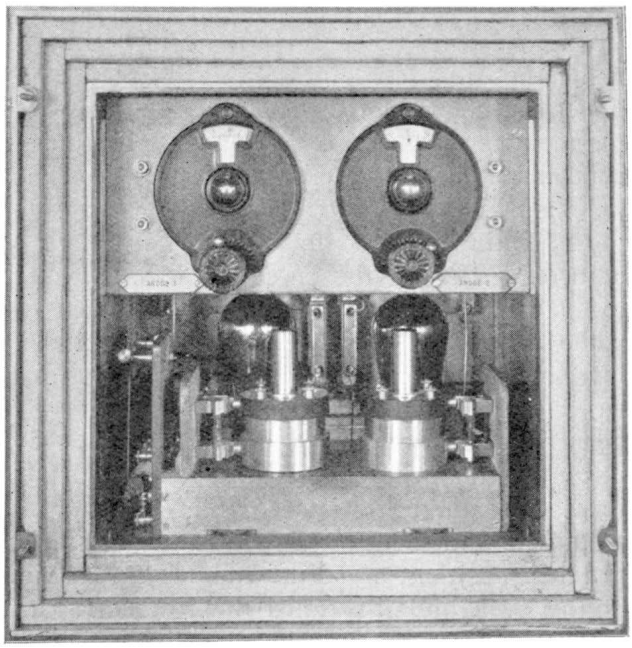


FIG. 8.—QUARTZ OSCILLATOR OVEN. CONDENSER PANEL IN POSITION.

Fig. **7** shows an oven with two similar quartz oscillators. The oven consists of two shells of aluminium separated by three layers of

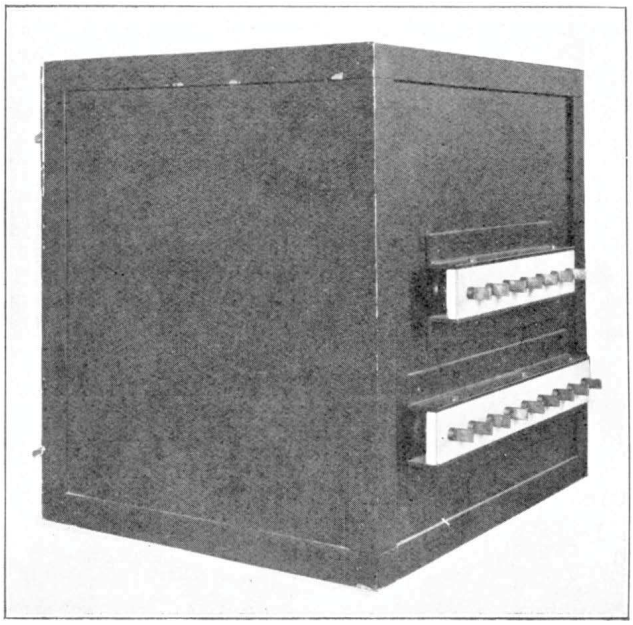


FIG. 9.—REAR VIEW OF OVEN.

" Celotex "—a building material manufactured from cane fibre. The crystal holders rest on a metal housing containing the oven heaters, bimetallic helix thermostat and nickel resistance thermometer. The arm carrying the thermostat contact is seen to the left of the heater housing, together with the worm gear by means of which the operating temperature of the helix may be adjusted. Behind the crystal holders are seen the valves and the output blocking condensers, while above are seen the anode coils and the mercury switch which selects the output from either of the oscillators. The anode tuning condensers are mounted on a mycalex panel which is connected to the circuit by switch contacts so that access to the interior of the oven may be readily obtained. Fig. **8** shows the condenser panel in position, and Fig. **9** shows a rear view of the oven and illustrates the rows of switch blades mounted on mycalex bars by which the various supplies are connected to the oven. The corresponding connections are carried on a panel (Fig. **10**) which serves for switching and metering the supplies to the oscillators. The switches and meters are described by the labels on the panel and there are, in addition, two fuse alarm lamps, an oven pilot lamp which indicates the operation of the thermostat contact and two filament rheostats of the " preset " type. The lay-out of the front of this panel is typical of present practice in transmitter equipment.

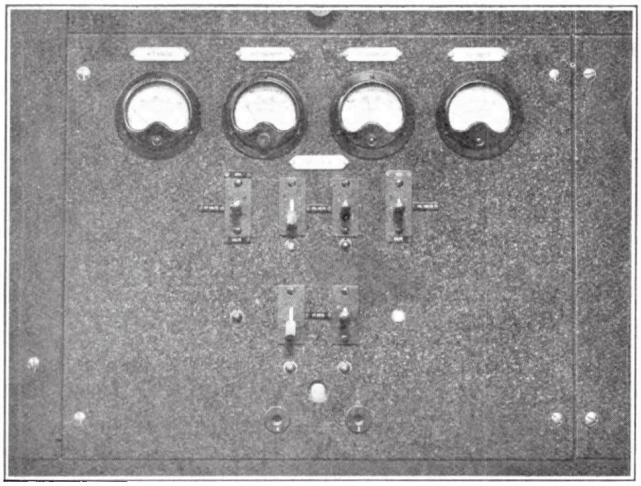


FIG. **10**.—OSCILLATOR METERING PANEL.

[*This article will be concluded in the next issue of this Journal.*]

(*Continued from page 166*)—

to eight or even to seven after being considered by the Secretary! However, on one occasion some " absent-minded beggar " drew out the wires and left an empty pipe! It was years before sweeps' rods for pipework were thought of. What was to be done? Somebody suggested a rat and length of twine. So far so good; but the rat thought it wise to settle down half-way and it was not until a ferret was sent in to discuss matters with him that he decided to finish the journey. I don't know whether it was the rat or the ferret who was rewarded! Mr. C. T. Fleetwood was the London Underground expert in those days—I do not know whether the rat idea originated with him or with one of his subordinates.

It would probably surprise many present-day Engineers to know that even when multiple ducts were first installed we used to run sash lines in those that were to be filled at once and iron wire in spare ducts. I find the need for a rat in these days a little perplexing.

I wonder if your readers would feel any interest in a " fishing " story? Soon after I succeeded Mr. Fleetwood at Met.N. one of my Engineers told me that they had been trying in vain for two or three days to get rods through a pipe in Hackney. " Fishing " from both ends by means of rods specially fitted with wire hooks had entirely failed, and he thought there was nothing for it but to open up midway. I discussed the problem and made a rough sketch of a spring coupling as a substitute for the " fishing " hooks. It was made by the mechanic, the two halves of the coupling were fixed on the sets of rods served from each end and they engaged as soon as they met! A few days later the Engineer explained that often it was difficult to rod a long section as the rearward rods spiralled in the duct owing to the weight of or the friction on the rods in front. I said that although the spring coupling would meet the case it would be interesting to try another device. So I had a " thick to thin " adaptor made and we passed forward thin rods until they bound and would go no further; then five or six lengths were withdrawn, the adaptor connected and the thin rods pushed forward by thick rods. This also was entirely successful. I duly submitted the Spring Coupling and a complete set of Adaptors to H.Q. and it was adopted.

Probably standardisation of cable lengths has abolished any need for such devices to-day—except at Turin!

Yours faithfully,

A. J. STUBBS,
Carlisle Lodge,
58, Howard Road,
S.E.25.

NOTES & COMMENTS

MICHAEL FARADAY was one of the greatest Englishmen that ever lived. He was a great man, not only by what he did but also because of his simple kindliness, which did not allow him to lose his head when honours were thrust upon him. His memory is revered at the Royal Institution, and it is fitting that that august body should combine with the Institution of Electrical Engineers to celebrate the centenary of the discovery of electromagnetic induction by Faraday in the year 1831. An exhibition will be held at the Albert Hall, London, for ten days, beginning on the 22nd September, which will illustrate the development of industrial science due to the intuition and work of this remarkable genius. The exhibition will coincide with the meetings of the British Association, and the I.E.E. will hold its annual conversationé at the hall on the 22nd September. The P.O. is to participate in the Communications Engineering section and arrangements are in train for a very representative exhibit of what is called sometimes,, although quite erroneously, light electrical engineering. In all the sections, the items will be arranged in historical order, from a statue of Faraday in the centre to the screen that will cut off the arena from the boxes.

In this issue we start a new venture in the shape of a Supplement to the Journal, one of which is enclosed in each copy. The main object of the Supplement is to cater for the needs of the younger members of the staff and the Department's workmen who have responded to our appeal in a most gratifying manner. In this number, the current year's C. and G's Magnetism and Electricity and Telephony Preliminary grade examination papers are answered by a capable officer of the Department. The other grade papers will follow in October. The addition of a Supplement throws a very heavy burden on the Board, but we think it will be appreciated and will, we hope, result in a still further increase in our circulation, which is now between seven and eight thousand copies per quarter.

Mr. Sydney Evershed, M.I.E.E., has sent us a copy of his Discourse given at the I.E.E. on the "Commemoration of the Centenary of the birth of David Hughes." We regret we have no room in this issue for the paper, which relates the life history and doings of a man whose inventions have been closely associated with telegraphs and telephones. He was a Welshman, born in London, but his father took him when a boy of seven to Virginia. He returned to London in 1857 with his telegraph printer, but, in the words of Mr. Evershed, John Bull said "No" to Hughes. In a few years the Hughes was at work all over Europe. In 1877 he invented his "microphone," and in 1879 the Induction Balance. In 1880 Hughes was elected a Fellow of the Royal Society and in 1885 he was awarded the Society's gold medal. He was president of the I.E.E. in 1886. He died on 22nd January, 1900, and in his will he left a large sum to scientific societies, the Hughes Scholarship to the I.E.E. and the greater part of his fortune to four London hospitals.

RATS AS DUCT THREADERS.

The story from Turin which we published in last issue has brought forth quite a large correspondence on the subject. First we have a protest from our venerable friend, Mr. C. B. Clay, who writes from Bromley, Kent, as follows :—

May 8th, 1931.

Dear Sir,

In your notes in the April number under the heading "Rats," you mention as original a story from Turin.

A very similar one was told to me in 1885 or 1886. In this case instead of the blow lamp a ferret was used with satisfactory result. I do not remember hearing the fate of the rat.

Surely you won't let Turin claim originality for a device used in Newcastle-on-Tyne more than 44 years ago.

Yours faithfully,

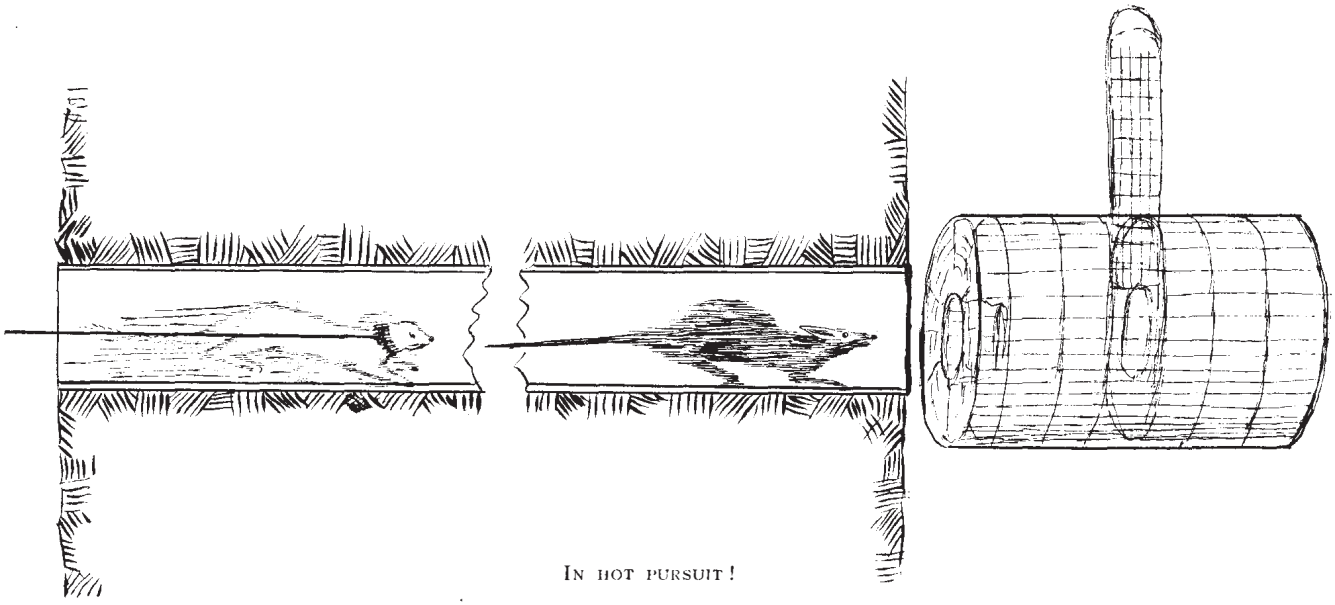
C. B. CLAY.

Then comes a letter from Mr. Procter, of the T.I. Group, who confirms the ferret edition, and gives a sketch illustrating the pursuit. We do not agree with Mr. Procter that the method has any advantage since the ferret might overtake the rat in the duct, and the evil would then be worse confounded!

11th May, 1931.

Dear Sir,

The account, in the last issue of the Journal, of the episode of the Turin rat was very interesting, but the method employed was surely crude and was certainly not original. Some years ago, I was searching through a pile of old electrical trade papers dating about the latter part of the 19th century and I recollect having seen a description in one of them of a method of getting a length of string through a duct; in the method described, a ferret was employed in addition to the rat. The article was illustrated and I enclose a sketch of the arrangement so far as I remember it.



IN HOT PURSUIT!

The rat was put into the duct and then the ferret, muzzled and with one end of a length of strong twine fastened to the muzzle, was sent down the duct after the rat. In theory, of course, both went with all speed to the far end where a double-compartment wire cage, such as is to be found on most farmsteads, was waiting to receive them. The rat having run to the end of the cage, the dividing partition was dropped in readiness for the reception of the ferret.

This method has the advantage of possessing a much greater degree of certainty in attaining the desired object, though I do not remember reading that it had ever been tried out in practice. Possibly, however, some of the older readers of the Journal may be able to relate actual experiences with the method.

Yours truly,
W. S. PROCTER.

Then our esteemed friend M. L. Kristiansen writes from Oslo and puts the seal, as it were, on the story by quoting from the classics :—

Dear Sir,

"And the rat came back."

The Italian process of using a rat for pulling or drawing wire into a telephone duct—told in your last issue—is anticipated by the time-honoured authority : Preece and Sivewright : "Telegraphy," tenth edition (1892), page 313—but of course the blow lamp has improved it (*i.e.*, the process—not the rat!)

Yours sincerely,
M. L. KRISTIANSEN
(Foreign Member).

And, lastly, Mr. A. J. Stubbs, whose veracity, we all agree, is beyond dispute, writes :—

To The Editor, *P.O. Engineers' Journal.*

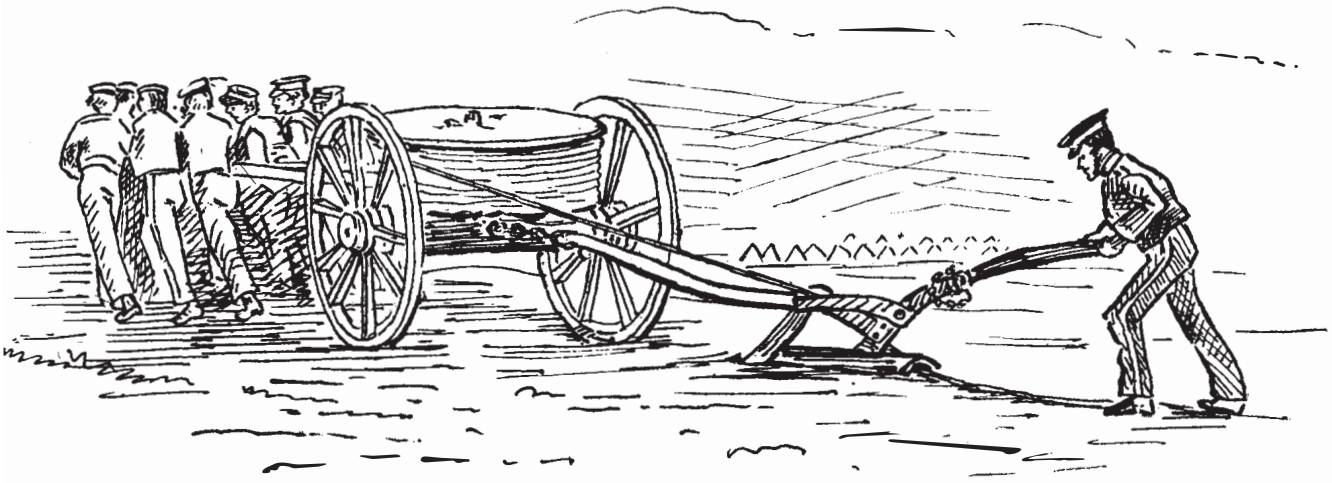
8th June, 1931.

Dear Sir,

Rats! There's nothing new under the Sun!

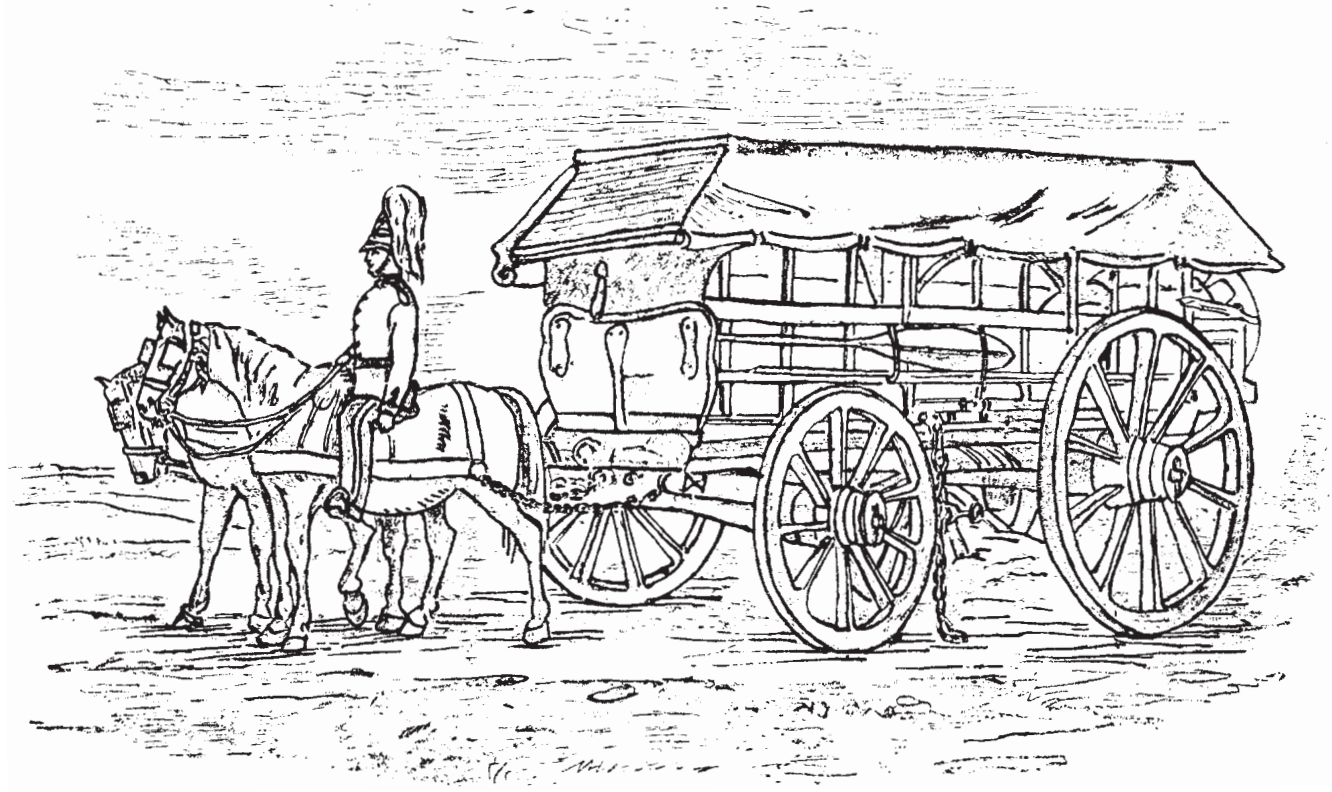
The most interesting point to me about Mr. Briggs' Rat Story on p. 66 is the implication that only the "absolute veracity" of the correspondent secured acceptance of the story. I trust that my veracity may be esteemed equally unimpeachable, because I want to assure you that this novel way of getting wires into a pipe was practised fifty years ago. In those days when a pipe was laid it was going to be used at once so it was sufficient to thread a sash line through as it was laid (This of course is not novel even to-day!) The gutta-percha covered wires were drawn in by its means (or by means of a larger rope). In those days an increase in the number of wires in a pipe was a very serious matter—an S.E's suggestion to increase by (say) ten wires might be reduced

(Continued on page 164.)



" Cannons to left of them volleyed and thundered."

PLOUGH FOR LAYING COVERED WIRE SUPPLIED BY THE ELECTRIC TELEGRAPH COY. CRIMEA, 1854.



TELEGRAPH WAGON SENT OUT TO THE CRIMEA, 1854.

HOW " SIGNALS " FUNCTIONED IN THE CRIMEAN WAR, 1854.

G.P.O.,
Gloucester.
11-5-31.

The Managing Editor,
P.O.E.E. Journal.

Sir,

Having read with interest about the experiment carried out in connection with the laying of cable in the grass margin, N.E. District (Vol. 24, Part 1, Page 73, April, 1931), I thought this picture might be of interest to you.

You are quite at liberty to keep this, also the one of the Utility Wagon.

E. F. G. HOBRO, SW.II.,
Gloucester.

LOCATION OF SPLIT PAIRS IN CABLE.

Research Station,
Dollis Hill.
19-5-31.

The Editor, *P.O.E.E. Journal.*

Locating the Crosses in Split Pair Cables.

Dear Sir,

In the April, 1931, issue of the Journal (page 71)

there appears under the above title an account of a somewhat novel method of locating split pair joints in cable sections of not more than about two miles in length. The use of the formula given for obtaining from the bridge reading the distance to the faulty joint would appear, however, to give rise to serious error, except in certain circumstances. This is because the formula neglects to take account of a number of capacity couplings between the wires, which would generally be large enough to affect the conditions for the balance of the bridge.

Fig. 1 corresponds to the figure given by Mr. Brown, but includes all the capacity couplings involved. The diagram has been simplified by combining, in the usual manner, the wire-to-earth capacities with the wire-to-wire capacities to give "resultant" wire-to-wire capacities. The significance of the letters used is as follows :—

W, X, Y, Z are resultant capacities between wires in different pairs.

M, N are resultant capacities between wires in the same pair.

Also,

$$W = w + \frac{ac}{a+b+c+d}, \quad X = x + \frac{bc}{a+b+c+d},$$

$$Y = y + \frac{bd}{a+b+c+d}, \quad Z = z + \frac{ad}{a+b+c+d},$$

$$M = m + \frac{ab}{a+b+c+d}, \quad N = n + \frac{cd}{a+b+c+d}$$

where w, x, y, z, m, n are direct wire-to-wire capacities, and a, b, c, d are direct wire-to-earth capacities.

Mr. Brown's method of joining the wires to the bridge enables capacities W_1, Z_1, N_1 and M_2, Z_2, Y_2 to be neglected, so long as the cable section is not more than a few miles in length.

The condition for silence in the telephone is then, essentially

$$\frac{Q}{P} = \frac{M_1 + W_2}{X_1 + Y_1 + X_2 + N_2} \quad \ldots\ldots(1)$$

Assuming that the two pairs are very similar and are well balanced, and that the capacity distribution is uniform, then

$$\frac{Q}{P} = \frac{M_1 + W_2}{2\bar{W}_1 + \bar{W}_2 + \bar{M}_2} \text{ (very nearly)} \ldots\ldots(2)$$

where $\bar{M} = \frac{M + N}{2}$

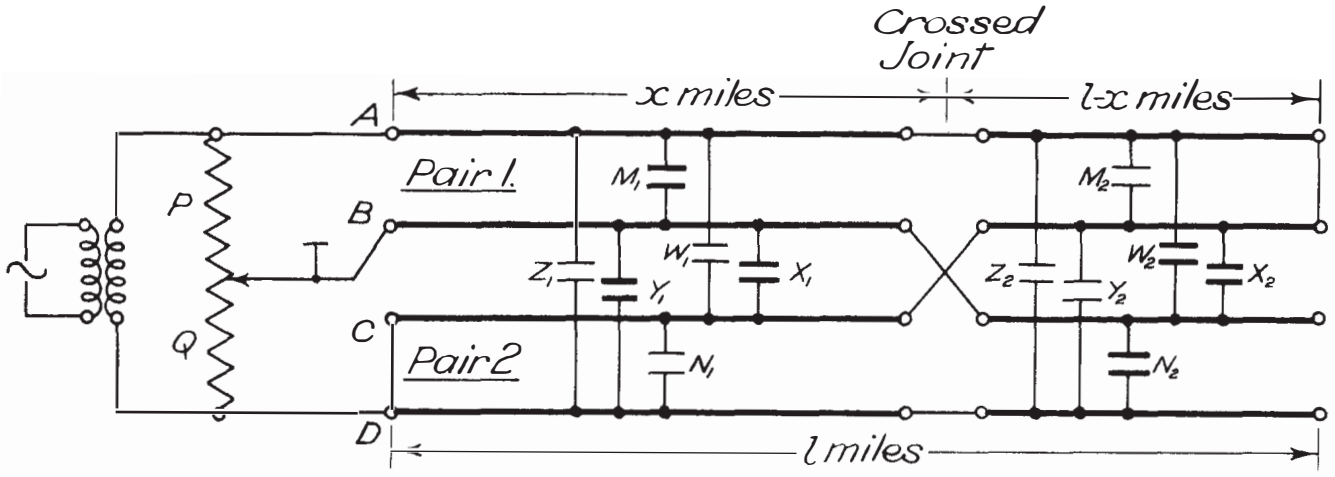


FIG. 1.

and $\bar{W} = \frac{W + X + Y + Z}{4}$

Also, it can be easily shown that in this case

$$\bar{C} = \bar{M} + \bar{W} \text{ (very nearly)}$$

where $\bar{C}$ is the average mutual capacity of the two pairs.

Substituting in (2) gives

$$\frac{Q}{P} = \frac{\bar{C}_1 - \bar{W}_1 + \bar{W}_2}{\bar{C}_2 + 2\bar{W}_1}$$

and therefore

$$\frac{Q}{P+Q} = \frac{\bar{C}_1 - (\bar{W}_1 - \bar{W}_2)}{\bar{C}_1 + \bar{C}_2 + \bar{W}_1 + \bar{W}_2} \quad \ldots\ldots(3)$$

By putting $\bar{W}_1 = \bar{W}_2 = 0$ in this equation we arrive at the equation (numbered (1)) given by Mr. Brown; but in general $\bar{W}_1$ and $\bar{W}_2$ could not be neglected.

Let $\frac{W_1}{C_1} = \frac{W_2}{C_2} = k$, which is justifiable on the assumption of uniform capacity distribution.

Then

$$\frac{Q}{P + Q} = \frac{C_1 - k(C_1 - C_2)}{(C_1 + C_2)(1 + k)}$$

On the same assumption

$$\frac{x}{l - x} = \frac{C_1}{C_2} \text{ and therefore}$$

$$\frac{Q}{P + Q} = \frac{x - k(2x - l)}{l(1 + k)} \text{ and}$$

$$\frac{x}{l} = \frac{\frac{Q}{P + Q}(1 + k) - k}{1 - 2k} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

This shows that in order to secure an accurate location it is necessary to know the value of the k for the cable pairs in question.

For $x = 0$

$$\frac{Q}{P + Q} = \frac{k}{1 + k} \text{ or } k = \frac{Q}{P} \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

For $x = l$

$$\frac{Q}{P + Q} = \frac{1 - k}{1 + k} \text{ or } k = \frac{P}{P + 2Q} \quad \ldots\ldots\ldots (6)$$

Putting $k = 0$ in equation (4) gives Mr. Brown's formula for the distance to the crossed joint. The effect of thus neglecting k can best be illustrated by specific examples.

Taking the case of Multiple-Twin cable, $k \fallingdotseq 0.4$, for pairs in the same quad, so that for $x = 0$, $\frac{Q}{P + Q} = 0.29$, and for $x = l$, $\frac{Q}{P + Q} = 0.43$. Thus, no matter what the distance to the fault, $\frac{Q}{P + Q}$ will never be less than 0.29 nor greater than 0.43; and the large error which may arise by using the relation $\frac{Q}{P + Q}$ to give $\frac{x}{l}$ is apparent. This error would not be cancelled by taking tests from each end of the line. It so happens that with the above value of k there would be no error if $\frac{x}{l}$ were equal to 0.35, but for values of $\frac{x}{l}$ greater or less than this, the error progressively increases. For $\frac{x}{l} = 0.2$, $\frac{Q}{P + Q} = 0.3$ giving an error of + 50%; and for $\frac{x}{l} = 0.8$, $\frac{Q}{P + Q} = 0.4$ giving an error of − 50%. These values, and also equations (4), (5) and (6) have been verified by experimental tests on a length of M.T. cable, pairs being looped up with crosses introduced at various distances from the testing end.

In Star-Quad cable, $k \fallingdotseq 0.65$, for pairs in the same quad, and therefore still larger errors would occur in this case. When the faulty pairs are not in the same quad, and also in the case of Twin cable, k would not be so large and the errors involved would probably be rather less. It is interesting to note that if k were exactly equal to 0.5, $\frac{Q}{P + Q}$ would always be 0.33 no matter what was the distance to the crossed joint.

Equation (4) shows that the method is only reliable when the factor k for the pairs concerned is known to a fair degree of accuracy. A value for k could be obtained by making use of equations (5) and (6); that is, by testing on "good" pairs in the cable and at the same time introducing a "split" at the testing end or distant end as the case may be. When the faulty pairs are in the same quad, a fairly accurate value could be secured in this way, but when the faulty pairs are in different quads, or if Twin cable is concerned, k will to some extent be dependent on the degree of adjacency of the faulty pairs in the successive cable lengths, and tests such as the above to find k would not necessarily give accurate results.

Alternative Method.—It may perhaps not be out of place to give a brief description of another method of locating split pairs which has been used. This method does not involve difficulties or sources of inaccuracies such as those discussed above and is not theoretically restricted by the cable section being either too short or too long. In this method the following capacities are measured on the faulty pairs (the wires being insulated at the distant end):—

(1) Measure the capacities A to B and C to D.
(2) ,, ,, ,, A to C and B to D.
(3) ,, ,, ,, A to D and B to C.

The mean of the two readings is taken in each case and calling these mean values K_1, K_2 and K_3 respectively, then if B and C or A and D are the crossed wires

$$\frac{x}{l} = \frac{K_1 - K_3}{(K_1 - K_3) + (K_2 - K_3)} \quad \ldots\ldots\ldots\ldots\ldots (7)$$

If A and C or B and D are the crossed wires

$$\frac{x}{l} = \frac{K_1 - K_2}{(K_1 - K_2) + (K_3 - K_2)} \quad \ldots\ldots\ldots\ldots\ldots (8)$$

The equation to be used in any given case can always be determined by inspection of the measured values of K_2 and K_3. The rule is that if K_2 is greater than K_3 use equation (7); and if K_3 is greater than K_2 use equation (8). There is one exception to this rule, viz., when the faulty pairs are

two pairs in the *same* quad in a Star-Quad Cable. In this case the rule is reversed because the capacity of a split pair is greater than that of a normal pair, whereas in all other cases the split pair capacity is less than the normal pair capacity.

When the fault consists of " rectified " split pairs, that is, when a second crossed joint has been made in an attempt to correct the first cross, x is the distance between the two crosses, and this information may sometimes be of help in deciding where first to open the cable. If the cable is opened between the two crosses, each can then of course be located in the usual manner.

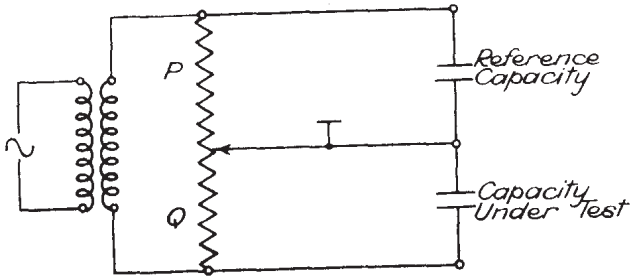


FIG. 2.

On short lengths of cable the measurements are generally made with a Wien bridge as used for ordinary mutual capacity tests on loading sections. On long lengths of cable, a ballistic method of measurement can be employed.

On short lengths, simple apparatus such as that suggested by Mr. Brown could be used with fairly accurate results, although in this case it would be preferable to secure the use of a properly graduated non-reactive slide wire having a resistance of 1000 ohms, or, alternatively, to use two resistances, of the order of 1000 ohms, in series, one of which is adjustable in steps of 1 ohm. The value of the fixed resistance need not be accurately known. A diagram showing the method of joining up the components is given in Fig. **2**, a small condenser (about 0.1 μF) or another cable pair being used as a reference capacity. Using this bridge the capacities K_1, K_2 and K_3 would be successively compared with the reference capacity.

If P_1/Q_1, P_2/Q_2, P_3/Q_3 are the ratios of K_1, K_2 and K_3 to the reference pair, equations (7) and (8) can now be written

$$\frac{x}{l} = \frac{P_1/Q_1 - P_3/Q_3}{(P_1/Q_1 - P_3/Q_3) + (P_2/Q_2 - P_3/Q_3)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (9)$$

and $$\frac{x}{l} = \frac{P_1/Q_1 - P_2/Q_2}{(P_1/Q_2 - P_2/Q_2) + (P_3/Q_3 - P_2/Q_2)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (10)$$

respectively.

In conclusion, it should be mentioned that a high degree of accuracy is not, as a rule, essential in locating faults of this character, which must always occur at one of the joints. This probably accounts for the success claimed when the method in question has been used. Nevertheless, its limitations are such that in the general case it would be much safer to employ the alternative method described in this letter.

Yours faithfully,
E. H. JOLLEY.

MR. THOMAS PLUMMER, M.I.E.E.

The many friends and colleagues of Mr. Thomas Plummer who are still in harness, and those in retirement, will regret to hear of his death, which took place after a short illness at his residence " Dunbrody," Port Hill, Shrewsbury, on the 12th March, 1931. Some four years ago, just prior to retirement, he suffered a somewhat severe illness from which he did not recover completely. It had been hoped that freedom from the increasing stress of official life, and the pursuit of interests at leisure would have given him many enjoyable years, but this was not to be, and he was laid to rest in the beautiful cemetery at Shrewsbury on the 16th March. He leaves a son and daughter, and two sisters, one of whom, Miss K. Plummer, has devoted many years of her life to her brother and his children.

A notice of his retirement appeared in the October, 1927, issue of this Journal. B.J.G.

HEADQUARTER'S NOTES.

REMOVAL OF TRAINING SCHOOL TO DOLLIS HILL.

The Training School which has so long been a feature of King Edward Building has removed to Dollis Hill and now forms part of the Research Section instead of the Telephone Section. As our readers are aware, Automatic Telephony in this country began on a small scale and elaborate training of staff could not be evolved for a considerable period. Soon after the close of the War, however, training became an important issue and it is largely owing to the perseverance of Mr. Anson that the present School was started at the end of 1924 and was installed in such a favourable position in the heart of London.

Since its inception the School has obtained a very high reputation, not only among the staff of the Post Office, for whom it was primarily intended, but also among our Manufacturing Firms and the staff of overseas Administrations. Such a reputation has been built up very largely by the helpful and stimulating atmosphere created by Mr. C. W. Brown, who is in charge of the School, and his staff of able assistants.

The removal of the School to Dollis Hill, therefore, does mark something of the close of an epoch in the history of training in this country, more particularly as since its inception its scope has been extended to cover training in transmission and other branches of work as well as in automatic telephony.

A few facts with regard to the removal may be of interest. The bulk of the Courses closed down on the 28th March, 1931, and the work of dismantling, for which preparation had already been made, began immediately. The whole of the apparatus, including racks and cabling, had been recovered in a period of two weeks and practically the whole staff transferred to the new headquarters on the 20th April. But it is of interest to note, too, that Courses on Rural Automatic Exchanges will continue throughout the period of the removal. In addition a course for Probationary Inspectors was commenced at the new headquarters on May 1st, so that it can be said that the work of the School was never entirely interrupted, even by the dislocation caused by the removal.

It is possible to look forward to a time when the School, its scope considerably extended, will be firmly established in its new headquarters and achieve an even bigger reputation there than in K.E.B.

TRAINED.

The Reactions to Training of a Probationary Assistant Engineer.

A complementary article to "Training," J.I.P.O.E.E., October, '30.

When training for the Olympic games, it is said that Grecian athletes practised for long periods with lead weights tied to their ankles. After such preparation it was thought that they would not easily tire in the actual race, for which, of course, the weights were removed. The Engineering Department of the Post Office undoubtedly has a similar end in view when training its employees, particularly the younger ones, but it seeks to accomplish its object by means less brutal and probably more effective.

In the anti-penultimate issue of this Journal an outline was given of the syllabus that had been followed during the early months of 1930 in the training of those Probationary Assistant Engineers and Inspectors who had entered these grades by examination. Accurate as may have been the information contained in that article, justice could hardly be done to the subject by the author concerned for reasons of personal modesty. In this article is given a chronological summary of a few of the reactions, which in retrospect stand out most prominently, of one who underwent the course of training.

It will make large demands on the imagination of those who have been engaged in situations for a number of years to conjure up recollections of the excitement which is engendered by the anticipation of taking up a new post. The excitement for most of us was enormous, being bolstered up by the great pride that we felt in ourselves in having attained an object on which we had been persistently intent from the moment that we completed the first official form in our existence, our entry form. Apart from having read sundry technical publications of the Department and possibly Sir Evelyn Murray's handbook treating of the general ramifications of the Post Office, most of us had probably gained our detailed knowledge of this much abused organization from the daily press.

The attitude of employers towards new members of their staff varies; naturally, they are to a large extent influenced by the impression that they wish to create. In our case, assessed by the extent of the desirable atmosphere it created, the welcome extended to us was conspicuous by the completeness of its success. On arrival, an official welcome was extended by some of the dignatories of the Department, not to the new entrants collectively, but to each one individually. Immediately we were handed over to the Training School, at that time (February, 1930) housed in King Edward Building; a period then followed in which every effort was made by the School staff to assist the new students to accommodate themselves to their fresh surroundings. Meanwhile to each one was issued suitable armour to carry him through the impending battle. Not the least amusing incident, at least to one who had entered from a very up-to-the-minute concern, where two weeks extra remuneration took the place of annual leave, was the appearance of the ubiquitous leave form, for, having entered the Service on the 10th February there would be leave accruing to us before the end of the "leave year," February 28th. Now as the course proceeded, an amazing thing transpired which was this, everybody in the Post Office was actually working hard; and, moreover, nothing was left undone that might be done to promote efficiency in that Department. This, of course, was absolutely contrary to the information that had been gained from wiseacres in the outside world; not that the writer is complaining of having been attracted into the Service under false pretences!

During the first three months of the course that was to follow in the Training School, it was to be our lot to assimilate the accumulated knowledge of the Accountant General and the Engineer-in-Chief; later we were to wander out into Engineering Districts to study how the knowledge of these two giants was being exploited. It is not possible for any syllabus adequately to describe the subject matter that was dealt with in the lectures; all the lecturers gave freely of their knowledge, not only of that part of it which is of necessity stereotyped and which could have been obtained from the regulations, but of that part of it which is sometimes absent from the Regulations and Technical Instruc-

tions, the detailed fruits of their experience. The subject matter was presented in the following sequence. The earlier lectures were confined to expositions on the administrative and organizing activities of the staff of the Department. Then, gradually, stage by stage, the lectures merged into those more directly associated with the activities of the average assistant engineer and inspector. The vast amount of detail which constituted a large part of these lectures might have proved monotonous but for the welcome relief of practical work. Demonstrations and informal lectures on External work were given by a lineman from the London Engineering District. The practical side of Overhead work was dealt with in a manner that no one less familiar with the details than an actual lineman could have equalled. On many occasions since these lectures has the writer been able to acquit himself with honour when it has been necessary to tie knots under conditions of great strain, *e.g.*, for towing a motor car, fixing a jam cover, etc. !

Among the Internal practical work was included the forming and lacing of cable, soldering, the dissection of apparatus that some of us had not had the opportunity of handling before on such familiar terms, the erection of, and identifying of faults on, subscriber's apparatus. Possibly amongst the Internal practical work might be included several conducted visits to manual and automatic exchanges. To anyone who has been bred in an atmosphere of manual working it may be difficult to conjecture how intricate does manual operation appear at first sight. On all these visits we were accompanied by two members of the School staff, who were our tutors and advisers while the lectures were in progress. Two visits were made to Contractor's works during the School part of the course, both of which left pleasant recollections (and valuable information) in the minds of the visitors. Spectacular and impressive as were the technical demonstrations that had been staged for us, undoubtedly these left a much smaller impression than did the hospitality extended.

As the time allotted for lectures grew less, the more did we appreciate how well we were being treated. No great exercise of the imagination is called for to realize how entertaining the course proved; every fresh member of the staff that we encountered endeavoured to convince us that we were having the time of our Departmental lives. Even as all good things come to an end so did the School portion of our training terminate at Whitsun, and, on Whit Tuesday we reported to the various Engineering Districts in which we were to proceed with the rest of the syllabus. The sensation was one of beginning a long journey, of several months duration in fact; now did each student go his own way, the Probationary Assistant Engineers for eighteen and the Probationary Inspectors for thirty-six weeks training in the Districts. So must the writer's tale be now considered individual, although on the various occasions on which he has had an opportunity of comparing reminiscences with his late colleagues a marked similarity of experience has always been observed. The description that follows centres round those things that are to be seen while training in a " country " section of the London Engineering District. Undoubtedly the staff of this section must have thought unkindly of the writer on not a few occasions, but with one exception, they were sufficiently sympathetic or discreet to conceal it.

The first six weeks of the District experience were spent in an external section. Having interviewed the probationer, the Sectional Engineer introduced him to the chief of his clerical staff. The latter, after furnishing the writer with a list of all the clerical duties in the office, introduced him to his assistants. It was then the writer's embarrassing privilege to take a chair and sit by each clerical officer, watching his every action and making copious notes, lest at any time in his career he should be called upon to organize a Sectional Engineer's office from " scratch." Concurrently the work of the Development office was studied. The study of Development technique was to prove exceedingly fascinating, for, not only was the actual planning of the schemes witnessed, visits being made to the sites during the survey, but later the checking of the plans in the Superintending Engineer's office and the execution of the work were seen. And now for the one exception to the generous welcome, it was that extended by a Plumber-Jointer whose work the writer was due to investigate in much the same way as he did that of the clerical officers. It was later discovered that this same man had on a previous occasion chased his Inspector with a spanner. *Verb. sap.*—especially to anyone who may seek information from a similar source.

In country sections in summer time, training in an Internal Section is no less interesting than in an External Section, and it was about this time that the writer began to find the way to make the most of the training resources at his disposal. For instance, not least of his discoveries was that U.S.W. was the abbreviation, not for Un-Skilled Workman but for Unestablished Skilled Workman. Another discovery of great utility was that of the standard method to be employed in gaining a man's confidence, namely, to assist him in arriving at satisfactory explanations, harmless to his dignity, for his having been " passed over," masterly phrase ! When the writer reported to Section Headquarters in the middle of June, the Internal course of training was begun in the reverse direction to that followed in the External training. The writer saw first a selection of the practical sides of Internal work, witnessing in turn, Section activities from a maintenance Inspector's office and in the various exchanges in his charge, Construction and Fitting. The study of the administrative aspects of the work were left until the last. Owing to the similarity between Internal and External administrative work this represented no great disadvantage. It is difficult to decide whether there is any choice between the two methods, taking the Administrative

or the " Practical " aspect first. Probably the reversal of the procedure, as explained above, is the more interesting. The first Inspector under whose care the writer was placed had in his charge a large variety of maintenance work, including one Director Exchange, one manual exchange in the Automatic area, and five recently constructed C.B. exchanges. Construction work was seen in progress in great variety, embracing such things as a Director exchange, a Rural Automatic exchange, complete manual exchanges and extensions thereto. To an onlooker, Fitting probably provides the maximum of entertainment, although apparently for those actively engaged on it the entertainment is tempered with a considerable amount of nervous strain. At this point of contact with the public everyone endeavours to show an exemplary front, although, not infrequently the odds against the department's staff are excessive, the odds amounting to anything from satisfying the many prospective (and other) subscribers who demand absolute precedence for their installations to the peculiar local conditions of their premises. Included in the good fortune of the Probationer was the realization of an old ambition, no less than that of pulling a real Fire alarm, and, for the purposes of unravelling the mysteries of the alarm system, of being given the free run of a large Fire station. The name of the Section may be had on application, although it is possible that the writer may have spoiled the pitch for other players.

And so the passage of time brought the training to its closing phase, the six weeks in the Superintending Engineer's Office. This, however, was brought to an early conclusion, for, after ten days, the author was despatched to his appointed rut or mountain slope. The first week, spent in ignorance of the impending change of headquarters, was organized according to the prescribed programme. The remaining three days were utilized in what a globe-trotter would refer to as an effort to " do " the Technical Section in that time. Thanks to the untiring consideration of the staff, these efforts to gain a superficial knowledge of this section's work were neither unpleasant nor unsuccessful.

During the entire course, and actually after it had finished, the members of the training School Staff who were responsible for its administration and those members of the staff of the Engineer-in-Chief's Office who were connected with it in any capacity, maintained an attitude of intense and kindly interest in the welfare of the students. The latter were persistently solicited to express their views on any alterations or additions to the syllabus that they thought could possibly add to the usefulness of the training. One is naturally led to speculate on the means by which the Department hopes to gain by its generosity, in proportion to the obviously large expenditure incurred by such a training course. Some of the means available are these; newcomers are deprived of any idea that they may have wrongly acquired that their new employer is going to force them to make bricks without straw; the Department endeavours to ensure that when the straw is distributed it will be put to the best advantage from the beginning, a minimum being required for practice. The new staff are inspired with confidence in the firm they are to represent and the goods they will have to handle. What proves of great use to the Probationer, and indirectly a benefit to the Department, is that as a result of the introductions gained to members of the staff in all quarters, including his late colleagues in training, the Probationer invariably knows good authorities to consult when occasion arises after the conclusion of the course. Encounters with the colleagues referred to above are always the scene of exchanges of new experience and advertisement of recent " discoveries." Let those who are not yet convinced of the mutual benefits emanating from such a course consider a " psycho-mercenary " aspect of the case. If the Department is willing to start its new entrants with such a large credit account, it can safely rely on even the meanest feeling some compunction in the necessity for paying it back and on the more magnanimous a compunction for repayment with interest !

G.B.W.H.

April 30th, 1931.

EXCHANGE EQUIPMENT.

The following works have been completed :—

Exchange.	Type.	No. of Lines
Preston	New Auto.	3790
Fulwood	,,	560
Newcastle Area (12)	,,	19500
Harborne	,,	1290
Leytonstone	,,	2470
Birmingham Northern	,,	5280
Birmingham Victoria	,,	2815
Evington	,,	800
Ayr	,,	1780
Prestwick	,,	510
Rainham	Auto Extn.	200
Tandem	,,	Positions
Stoke	,,	P.A.B.X. Selectors.
Macclesfield	,,	Re-arrangements
Perth	Manual Extensions.	360
Bexhill	,,	Observation Equipt.
Truro	,,	240
Eccles	,,	560
Hastings	,,	Observation Equipt.
Maggs & Co. (Bristol)	P.A.B.X.	30
Lesme, Ltd. (Willesden) ...	,,	30
Cumberland C.C.	,,	20
King & Hutchings (Uxbridge) ...	,,	30

Orders have been placed for the following works :—

Exchange.	Type.	No. of Lines
Castle Bromwich	New Auto	300
Wordsworth	,,	2440
Bowes Park	,,	3580
Valentine	,,	4100
Park (Dundee)	,,	1020
Springfield	,,	2000
Wolverhampton Area (6) ...	,,	7500
Hunslet	,,	730
Adel	,,	300
Horsforth	,,	700
Corstorphine	,,	680
Middleton	,,	900
Tipton Area (5)	,,	2880
Gibbet Hill	,,	400
Churston	,,	200
Pinhoe	,,	200
Failsworth	,,	1300
Walkden	,,	500
Urmston	,,	1200
Ardwick	Auto Extn.	Routiner Equipment. Re-arrangements
Coventry	,,	,,
York	,,	1140
Ipswich	,,	Re-arrangements
Hove	,,	

Exchange.	Type.	No. of Lines
Portslade	Auto Extn.	710
Leeds	,,	800
Hillside	,,	Routiner Equipment.
Collyhurst	,,	,,
Colchester	,,	Observation Equipment.
Newbury	New Manual	1080
Northwood	,,	1600
Uxbridge	,,	1900
Pinner	,,	3500
London Trunk Record and Demand Suite	,,	Positions.
St. Albans	Manual Extensions.	Observation Equipment.
Kilmarnock	,,	240
Morris Cars (Smethwick) ...	P.A.B.X.	50
L.C.C.	,,	300
Cumberland C.C.	,,	20
Chapman, Ltd. (Taunton) ...	,,	20
Courage & Co. (London, S.E.)	,,	30
Thorpe Meadows and Co. (Hastings)	,,	20
Norton Grinding Wheel (Welwyn)	,,	30
Burnley Corporation	,,	30
McIlroy, Ltd. (Reading) ...	,,	30

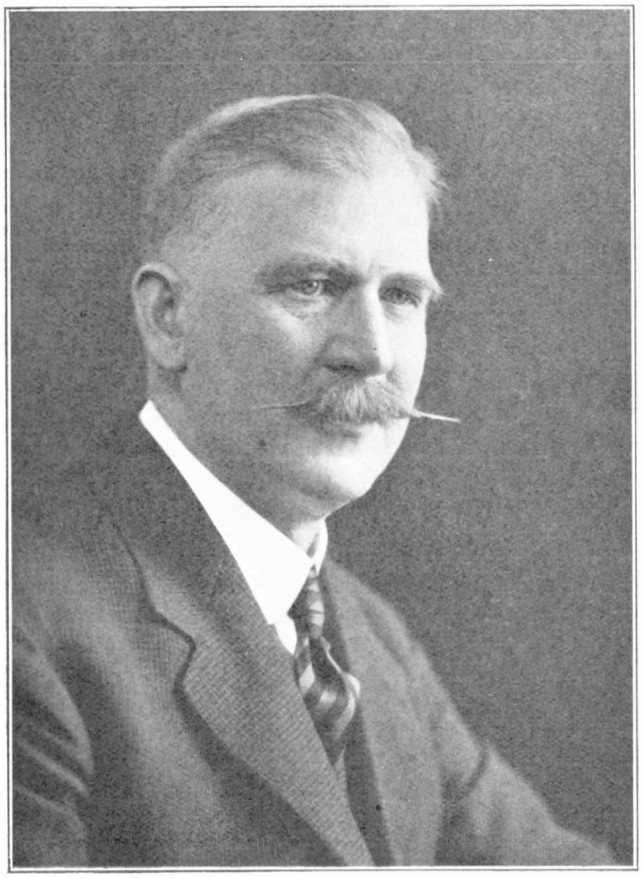
MR. E. H. SHAUGHNESSY, O.B.E., M.I.E.E., M.I.R.E.

By the retirement of Mr. E. H. Shaughnessy, Assistant Engineer-in-Chief, on 30th June, 1931, the Post Office Engineering Department loses an outstanding and popular member of its staff.

Mr. Shaughnessy entered the service of the Post Office as a telegraphist at the Central Telegraph Office in April, 1887. He was transferred to the Engineering Department as a sub-engineer in 1896, and he passed through the ranks of 2nd Class Engineer (1898), 1st Class Engineer (1901), and 2nd Class Technical Officer (1903). The operation of the scheme introduced by Major O'Meara by which Headquarters officers were required to serve in provincial districts resulted in Mr. Shaughnessy taking up duty as Assistant Superintending Engineer in the Eastern District in 1908. In 1913 he returned to Headquarters as the Staff Engineer in charge of the Radio Section. He became Assistant Engineer-in-Chief in 1925, the appointment being a new one, created " for wireless services," in connection with the second Imperial Wireless Scheme, adopted on the recommendation of the Imperial Wireless Telegraph Committee presided over by Sir Robert Donald.

The scope of Mr. Shaughnessy's early activities was extraordinarily wide. In addition to service in the Test and Telegraph Sections he took part in the experimental work in transmission which followed the development of the air-space paper core cable : he served as a cable engineer on the s.s. " Faraday " during the laying of cables in the Gulf of Mexico, and he took charge of the Experimenting Room in G.P.O. (West) when one room sufficed, or, rather, was the only space allotted, for development and research work in the Engineering Department.

It is as a radio engineer that Mr. Shaughnessy will be best remembered, and it is largely due to his energy, foresight and forceful handling of problems arising, as well as to his highly successful methods of selecting, training and using staff, that the Post Office is now in possession of radio-telegraph and radio-telephone services and equipment which are second to those of no other Administration. He took charge of the Radio Section when radio had barely passed the stage of infancy, although it was a healthy child, giving every promise of attaining vigorous maturity. The Coast Stations round the British Isles had been purchased from the Marconi Company four years earlier, and their equipment was in course of replacement and improvement. The proposed Imperial Wireless Chain of Stations was the subject of much discussion and comment, and, in 1913, a contract was entered into with Marconi's Wireless Telegraph Company for their erection. War broke out, and the contract was cancelled in 1915. The Company sued for breach of contract and were awarded damages approaching £600,000. Mr. Shaughnessy acted as an expert technical witness for the Crown in this case. It was a severe set-back, brought about by extraordinary conditions



Mr. E. H. Shaughnessy.

beyond the control of either Post Office or Company, but the lesson was not lost, and henceforth the Radio Section, with Mr. Shaughnessy as its leader, aimed at an organisation which, in the technical sense, would make it master of its own fate.

During the early period of the war, Mr. Shaughnessy was responsible for the measures taken for the detection of illicit wireless transmission, a phase of war activity which had its foundation more on rumour than on actual fact. A number of investigations were made of alleged or suspected infraction of the regulations without any serious case coming to light. Later on, he undertook the organisation and control of the Direction Finding Stations, the function of which was to identify and locate the movements of enemy aircraft during their voyages to this country on bombing expeditions. The scheme proved highly successful and gave material assistance to the Home Defence Forces in their efforts to discourage the intensification of this form of enemy warfare. Mr. Shaughnessy was made an Officer of the Order of the British Empire for his services in this connection.

With the restoration of peace, the work of recruitment and training of staff for further radio development was undertaken. A small group of able young men was added to Mr. Shaughnessy's pre-war staff. The first task to be undertaken was the completion of the Leafield and Cairo stations, the sites for which had been acquired for the Imperial Scheme, and on which the erection of buildings and masts had been commenced. The choice of the system of transmission for these stations of a power of 250 kilowatts was a matter of some concern. Valve transmission had not reached the stage at which the handling of anything approaching this power was possible. After careful consideration the Elwell-Poulsen Arc System was recommended by Mr. Shaughnessy as being the only system, available at that time, capable of producing the required amount of continuous wave high frequency energy for the services in contemplation. Leafield and Cairo were completed, and put into operation in 1922, and the success of Leafield in particular, from the references made to it, seems to have been largely responsible for inducing the Donald Committee to report upon the larger issue of the new Imperial Scheme in terms of Post Office ownership and control.

In the meantime Mr. Shaughnessy had set his staff to work on the problems of valve transmission. Experiments at Caister and Stonehaven were followed by the building of valve transmitters at these stations with powers of approximately 1½ and 25 kilowatts respectively, using in the latter case the output of six air-cooled valves. The Stonehaven transmitter replaced an arc transmitter, and a similar process of replacement was followed at Northolt where a 30 kW. set was constructed, the output being from three 10 kW. water-cooled valves. The Northolt transmitter utilised on a small scale the methods which it had been decided to adopt for the Rugby transmitter, preliminary steps for the construction of which had already been taken.

On the 5th March, 1923, the Prime Minister (Mr. Bonar Law) made the following announcement in the House of Commons, "... the Government has decided that it is necessary in the interests of national security that there should be a wireless station in this country capable of communicating with the Dominions and owned and operated by the State." The design of the new station was entrusted to the Wireless Telegraphy Commission, which was originally appointed under the chairmanship of the late Lord Milner, with Dr. W. H. Eccles, Mr. L. B. Turner and Mr. Shaughnessy as members. The site chosen was at Hillmorton, near Rugby, and the task of design in detail, in accordance with the principles laid down by the Commission, and the erection of the station, were undertaken by the Post Office Engineering Department. Mr. Shaughnessy thus served in a double capacity, and the Rugby station may be regarded as his radio *chef d'œuvre*. The design provided for an aerial power of 500 Kilowatts from 54 10 kW. water-cooled valves. Nothing had previously been done in valve transmission which approached this figure in power handled, although, as already stated, some of the methods used, including water-cooled valves and tuning fork frequency control, had been employed in

the Northolt transmitter completed a short time before. The transmitter, with its 820 ft. masts, dominating the surrounding countryside, was completed, tested and put into operation without serious hitch or accident. Rugby was, to a large extent, a plunge into the unknown, and although it is not in the official records, Mr. Shaughnessy probably breathed a sigh of relief when aerial current reached the 500 ampere mark and reports of reception arrived from the uttermost parts of the earth. Actually it was found that the aerial current aimed at was capable of being exceeded by over 50%.

Rugby, GBR, has been described in detail in numerous articles in this Journal, as well as by Mr. Shaughnessy himself in the paper which he read before the Institution of Electrical Engineers on 14th April, 1926; in a paper by Messrs. Hansford and Faulkner before the same Institution, and by Col. Angwin and Mr. T. Walmsley at the Institution of Civil Engineers.

Rugby was a worthy effort of the man who was mainly responsible for seeing it through, Mr. Shaughnessy. Throughout the task he never faltered in his belief in himself, or in his confidence in the subordinates, to whom he was proud to ascribe most of the credit.

The Imperial Wireless Telegraph Committee, 1924, recommended the construction of high power stations in this country capable of communicating with similar stations in India, South Africa and Australia. Canada was added to this list. The British stations were erected for the Post Office under contract by Marconi's Wireless Telegraph Company, the system adopted being that known as the " Beam "; short wave with directive antennæ. A great deal has been said and written about the attitude of Post Office engineers towards the " Beam " in its early days, with the usual exaggeration and lack of accuracy, but the outstanding fact is that, when information was forthcoming of its ability to perform the task required from the new Imperial Scheme, it was adopted wholeheartedly by the Post Office staff and worked to its utmost capacity. Mr. Shaughnessy was largely concerned in this decision, and the task of supervising, testing, accepting and working the stations erected under the contract fell upon him. The complaint against Post Office ownership of the " Beam " stations turned, not on inefficient handling of them, but on their ability to attract traffic from the older cable services. A very large amount of new traffic was also created by the lower rates in operation. The " Empiradio " system was, indeed, a highly successful business venture which probably more than fulfilled the hopes of the Committee responsible for its creation, while the Marconi " Beam " was tried out under Post Office management with a thoroughness which it would probably have obtained in no other circumstances. The Imperial Wireless and Cable Conference which was assembled in 1928, " to examine the situation which has arisen as a result of the competition of the Beam Wireless with the Cable Services . . . . " reported in favour of the amalgamation of the two interests by a merger of the Eastern and Associated Telegraph Companies and Marconi's Wireless Telegraph Company, and the transfer of the Empiradio and Government cable systems to the Merger. The report was adopted and the scheme put into effect by the Government of the day, and thus ended the episode of the Beam, so far as Post Office operation of the system was concerned. Whether this was a case in which it was wise to subordinate the new art to the requirements of the old only the passage of time can fully reveal.

The original long wave channel of the American radio-telephony service was developed and brought into operation during Mr. Shaughnessy's *regime*, and his experience and knowledge contributed greatly to its success. Mr. Shaughnessy should also be given credit for the later short wave developments which were made possible largely owing to the efficient organisation which he had set up, and to his selection and training of expert staff.

Mr. Shaughnessy has taken more than his full share of extraneous work, incidental to his profession, but much of it outside the scope of his official duties. Apart from his membership of the Wireless Telegraph Commission he served for a time on the Radio Research Board, on several committees of the British Engineering Standards Association and on the Royal Society's National Committee of the International Research Council. In 1921 he attended as a delegate at the Inter-Allied Technical Conference on Wireless Telegraphy which was held in Paris, and in 1922 he went to Brussels as one of the representatives of the Royal Society at the Assembly of the International Research Council of the Union Internationale de Radiotelegraphie Scientifique. He has been a Member of Council of the Institution of Electrical Engineers for a number of years and he is a Past Chairman of the Wireless Section. He is also a Vice-President of the Radio Society of Great Britain. He has served as Treasurer and as Chairman of Council of the Institution of Post Office Electrical Engineers, and he was for many years Chairman of the Board of Editors of this Journal. He has also undertaken the duties of examiner in Telegraphy for the City and Guilds of London Institute.

Mr. Shaughnessy attended the International Radiotelegraphic Conference at Washington in 1927, as one of the British delegates, and he served as President of the 2nd Technical Sub-Commission during its proceedings.

Mr. Shaughnessy was for a number of years lecturer in telegraphy and cognate subjects at the Northampton Institute and other technical colleges. His old students will remember the thoroughness with which he hammered in fundamentals, and the delight with which his not infrequent sallies of humour, largely at his own expense, were received. Mr. Shaughnessy's facility for the descriptive presentation of technical subjects has caused him to be much sought after as a lecturer on Post Office achievements in radio, and his orations have been

delivered apparently with equal enjoyment to his audience and himself. He is, indeed, a man who in addition to knowing his subject thoroughly has the gift of imparting information to others in an interesting and entertaining manner.

During the last few years of his service Mr. Shaughnessy was concerned mainly with staff matters. His strict sense of justice and his ability to inspire confidence in his judgment made it a foregone conclusion that he would be successful in this sphere. He discussed claims and grievances with representatives of staff associations on a footing of equality of interest, and the many agreements which have been obtained and put into operation are the best possible evidence of his conciliatory methods and of his skill in negotiation. At the same time the staff associations of the Engineering Department, in addition to obtaining substantial advantages, have gained, what is perhaps of equal importance, a reputation for moderation and reasonableness which should stand them in good stead in further negotiations for a long time to come.

Time appears to have dealt lightly with Mr. Shaughnessy and he has reached the age of retirement while still enjoying the vigour and the outlook of youth. It will be the earnest wish of all with whom he has been associated, and especially of his friends and colleagues—in his case the terms are synonymous—in the Radio Section, that this happy state of affairs may long continue. Mr. Shaughnessy has always played the straight game and he has reaped his reward in the universal esteem in which he is held. Our best wishes go with Mr. Shaughnessy and his family in his retirement.

C.J.M.

MR. A. B. HART, M.I.E.E.

ASSISTANT ENGINEER-IN-CHIEF.

MR. A. B. HART.

MR. HART is a Cambridge man and was educated at St. John's College School in that city. He entered the Post Office service as a telegraphist in the Cambridge office in 1893, but was transferred to the engineering side in 1896 when he entered the S.E's office as a Junior Clerk. In March, '98, he was selected for service at headquarters and came up to the Chief's Office as a 3rd Class Clerk. He had been studying technical matters and while in the head office he took the opportunity of attending the courses at the Northampton Institute and the People's Palace, and secured the C. and G's Silver Medal for Telegraphy.

In those days clerks with technical bent in the engineering department were eligible for engineers, and in 1901 Mr. Hart was promoted to a 2nd Class engineership in South Wales. In 1907 he was promoted to the First Class and placed in charge of Brighton section.

Mr. Hart was successful in passing a Civil Service examination for 2nd Class Staff Engineer (the grade is now known as Assistant Staff Engineer) and returned to headquarters in 1909, where he joined the transmission group under the control of the late Mr. A. W. Martin and took over the group when Mr. Martin died. At that time the underground trunk network was in progress of development, and during the seventeen years Mr. Hart was an Assistant Staff Engineer he was engaged entirely on this work and greatly fostered the growth of the system, introducing loading and superintending the installation of the chain of repeater stations which make long distance telephony possible on small

gauge underground conductors. On the 1st November, 1928, he took over the charge of the Lines Section, and now he has been promoted to be an Assistant Engineer-in-Chief. He was one of the original members of the C.C.I. and attended the first meeting in Paris, in 1923, with Col. Purves and Mr. J. G. Hill.

So much for his official career. Mr. Hart has a fine pair of hands and drives a straight ball at golf, when he can find time. He is also a first rate mechanic and keenly interested in motoring, his first licence dating from 1903. Born and bred in the country, he lives there now. His wife, a farmer's daughter, aids and abets him in his unofficial capacity as a yeoman of England.

CAPTAIN J. G. HINES, M.I.E.E.

Capt. J. G. Hines.

Captain Hines entered the Post Office Engineering Department in March, 1900, and was employed as a draughtsman in the preparation of the scheme for telephoning London, which the Post Office was about to undertake. Subsequently he assisted in supervising the provision of the initial underground plant. Most of the methods were new and much ingenuity had to be exercised to overcome the difficulties inherent to new systems.

When the installation of the Common Battery Exchanges commenced, Capt. Hines was employed as Assistant Engineer in supervising some of this work.

In 1905 he was transferred to the Engineer-in-Chief's Office, where he wrote the first edition of Technical Instructions XIV, which described the new methods of underground plant provision and also various special appliances, some of which he had designed. Included in these were motor-driven desiccators and winches, and it is interesting to recall that the P.O. Engineering Department was one of the pioneers in the introduction of portable machine-driven plant to replace heavy manual labour. In 1909, Capt. Hines went to the Test Section and was engaged in testing cables and other engineering plant at manufacturers' works. In 1911 he returned to the London Engineering District as Executive Engineer of the City Internal Section. While in this Section he established a school for telephone fitters and faultsmen, with the necessary equipment for giving adequate training. It is believed that this was the first of its kind.

During the war Capt. Hines served for a period in Mesopotamia and subsequently came back to England and organised training courses for Signal Service officers and men. On his return to civil life, he was placed in charge of the Technical Section of the London District and prepared a lay-out scheme for the introduction of automatic working.

In 1925 he was appointed Assistant Superintending Engineer in the London District and was principally engaged in the execution of the scheme above referred to and the provision of plant to provide for growth.

In 1924 he received the Senior Silver Medal of the I.P.O.E.E. for a paper on the lay-out of multi-exchange areas, and in 1930 he was awarded the "Webber Award" of the Institution of Electrical Engineers for a paper on "The Economics of Plant Provision."

MR. W. J. BAILEY, M.I.E.E.

Mr. W. J. Bailey.

Mr. Wm. J. Bailey was educated at Peckham Birkbeck School and passed an Open Competitive Civil Service Examination for male telegraph learners and was appointed skilled telegraphist at the Central Telegraph Office, London, on the 29th August, 1885. He studied technology at the Telegraphists' School of Science under the then Mr. William Slingo.

In January, 1896, he was transferred as Acting Sub-Engineer to the Electrician's Room, Holloway Factory, and was engaged chiefly in testing Trunk Switch Sections, etc. In November, 1896, he took up duty as Sub-Engineer at Sunderland, in which district the Post Office was in serious competition with the National Telephone Coy. He received commendation for various improvements which he effected in the Secret Switching System in use in that District at that time. In November, 1899, he was promoted to the grade of 2nd Class Engineer at Sunderland. From 1898 to 1906 he held lectureships in Technical Telegraph and Telephony at South Shields Higher Grade Schools, the Sunderland Technical College and Armstrong College, Newcastle-on-Tyne. In November, 1906, he was appointed 1st Class Engineer at Bradford. In December, 1908, Mr. Bailey passed the Civil Service examination for 2nd Class Staff Engineer and was appointed to the Designs Section, E.-in-C.O., in April, 1909, where he took a very active part in the introduction of the first Automatic Exchanges and wrote comprehensive technical descriptions of the Strowger & Lorimer Systems, which were published in this Journal, Vols. 5 & 6.

On 23rd March, 1927, he was appointed Staff Engineer, in charge of the Equipment Section, succeeding the late Mr. M. Ramsay as Chairman of the London Automatic Committee.

Mr. Bailey initiated the Section swimming club and presented a Challenge Cup for competition He took a very active part in the Engineer-in-Chief's Social & Sports Club, being chairman of the Central Committee.

MR. BERNARD OGLIE ANSON, M.I.E.E.

Mr. B. O. Anson was promoted to be Staff Engineer in charge of the Equipment Section on 1st June last. He entered the telegraph service of the Post Office in 1896 and began his career in the Engineering Department in 1903.

Characterised by a progressive outlook, it is natural that Mr. Anson should have been identified from the outset with the introduction of Automatic Telephony into this country and that he should have been prominently associated with every stage of development of automatic telephones in their application to the British Post Office telephone system. He was a member of the Commission that visited the United States of America with Sir William Noble to study automatic telephone systems in 1919, and he has also made official and semi-official visits to France, Holland, Sweden, Japan, China, India and Egypt.

In 1929 his services were placed at the disposal of the Shanghai Municipal Council to investigate and report upon the telephone system of that city. The report which he presented to the Council at the end of a few weeks visit to Shanghai was far-reaching and convincing. Such was the confidence of the Municipal Council in Mr. Anson's ability and judgment, that his report was adopted in its entirety and

MR. B. O. ANSON.

his recommendations are now in course of being implemented, notwithstanding the fact that their adoption involves the rebuilding of the Shanghai telephone system within a period of two years at a capital cost exceeding one million pounds.

Mr. Anson instituted, organised and planned the Engineer-in-Chief's Automatic and Repeater Training School, which is known throughout the service as a model of efficiency and which has contributed so largely to the successful introduction and maintenance of automatic telephones in the London and other important areas.

The success which has attended the widespread introduction of Rural Automatic Exchanges throughout the country during the past few years is also largely due to Mr. Anson's foresight and energy and his ability to achieve important results quickly.

Always keenly interested in the training of personnel he was a member of the Committee on the Training of Probationary Engineers and Inspectors and of the Committee on the Training of Youths. He has also been a member of the following and other Departmental Committees :—Work and Staff of the Engineer-in-Chief's Office, Co-ordination of Development and Research, Design of Automatic Systems for London and Large Cities, Traffic Control for Automatic Exchanges.

He is Examiner in Telephony for the City and Guilds of London Institute and in the same subject for the Graduates examination of the Institution of Electrical Engineers.

His wide experience of negotiation in matters connected with staff conditions caused him to be chosen as first Joint Secretary of the Official Side of the Departmental Whitley Council when Whitleyism was first introduced into the Engineering Department.

Readers of this Journal will be familiar with the name of Mr. B. O. Anson. He has been an energetic member of the Board of Editors for many years and has been Chairman of the Board since 1926. His Chairmanship is distinguished by the same spirit of progress and enterprise as he displays in all his official and other activities. He is also a Member of Council of the Institution of Post Office Electrical Engineers and is Treasurer to the Institution for the present year.

MR. J. J. MARKWICK.

MR. MARKWICK retired from the service at the end of March last, having reached the allotted span. His name had been associated for many years with Fire Alarms, but it is a mistake to think his activities were confined entirely to that branch of the Department's manifold services. As Assistant Staff Engineer in the Designs Section he was responsible for Telegraph apparatus and he was also entrusted with the task of standardising telephone subscribers' apparatus.

He, like Mr. Shaughnessy and many other well-known men, graduated in the hard but bracing school of TS and was promoted Sub-Engineer with headquarters in the Electricians' Room, Holloway Factory. While there he won the medal for Telephony, Final grade. Sir T. F. Purves, then plain Mr. T. F. P., selected Mr. Markwick to take charge of and test out the installation of the Metropolitan Inter-Com Switch by the B.I. and H. Coy. When the board was taken over by the Department Mr. Markwick went to assist Mr. Sinnott in the Designs Section on Fire Alarms and soon made himself master of the various systems then in use and developed and improved the L.C.C. and other corporation services. He passed through the grades of Second Class, Assistant and Executive Engineers

and then succeeded the late Mr. McInnes as Assistant Staff Engineer, all in the Designs Section. During the war he carried out many experiments on the use of the buzzer with search coils for various purposes and also on the Fullerphone. He retires with the best wishes of his many friends in the Department and outside. In his youth he was an enthusiastic cyclist and spent many holidays on tour in Europe. He has now turned his attention to motoring and has already covered most of the roads in the fine country that lies north, west and south of Harrow.

DISTRICT NOTES.

LONDON DISTRICT.

Growth of Telephone System.—During the quarter ended 31st March, 1931, the nett additions in exchange lines and stations amounted to 6,343 and 10,033 respectively. The total is now 413,882 exchange lines and 696,108 telephone stations.

The total loop mileage of telephone wire is 1,514,622. This includes the junction and trunk mileage. The number of telephone kiosks in the London area now exceeds 2,300 and additions are being made daily.

New Automatic Exchange.—The Leytonstone exchange was opened on Thursday, 7th May, at 1.30 p.m., with the transfer of 1,786 subscribers' lines, of which 780 were transferred from the hypothetical exchange at Walthamstow, 516 from Wanstead and 490 from Maryland. The exchange was installed by the General Electric Company, Limited, and has an initial capacity of 2,470 lines with an ultimate capacity of 10,000. At the time of opening 186 outgoing and 146 incoming junctions were also brought into use.

The successful nature of the transfer may be gauged from the fact that in the post-transfer tests, which were completed in an hour and a half, only two subscribers lines were faulty and not a single junction was out of order.

New Trunk Record Positions G.P.O. South.—The new suite of Trunk Record positions on the 5th floor, G.P.O. South, installed by Standard Telephones and Cables Limited, in conjunction with the local staff, was brought into use on the afternoon of Saturday, May 9th. The positions, which number 60, are arranged in three suites, and will in due course be utilised for combined Record and No Delay working, but at present they will only be used as Record positions, in replacement of the existing suite on the 1st floor. Ultimately, the outgoing junction multiple on these new positions will accommodate circuits to the main Trunk centres and thus enable direct connections to be made. For the present, the record tickets will be made out in the usual way and passed, *via* ticket tubes accessible to every operator, to a central point from which they can be retransmitted by tube to the appropriate Trunk position.

Prior to the transfer, a complete test was made of every calling circuit and cord circuit, both from the Trunk Main Frame and the distant exchange manual board. The transfer of the record lines was effected in three groups, viz. :—

Group I.—3.0 p.m.—3.30 p.m. All single record circuits from London Exchanges.

Group II.—3.30 p.m.—4.0 p.m. The second half of each group of more than one.

Group III.—4.0 p.m.—4.30 p.m. The first half of each group of more than one.

The arrangements thus made enabled continuous service to be given from all exchanges in the London area during the change over period. Subsequent to the transfer a test was made of all circuits from all manual and automatic local exchanges and indicated that the whole transfer was satisfactory.

Gamewell Fire Alarm System.—Reference was made in the last issue to the installation of a new Fire Alarm System for the London County Council in the Southwark area. The new system, on which the apparatus was installed by Standard Telephones and Cables, Ltd., was brought into use on Tuesday, May 5th, and was regarded of such importance that many of the officials of the L.C.C. and Fire Brigade were present to see the system in operation. The following additional details may be of interest :—

Two loops are provided in the Southwark area with 28 call points in all. These loops are continued on junctions from the Southwark Fire Station to Whitefriars Superintendent Station, where four batteries, of which two are standbys, and each composed of 90 10-A.H. cells of the Chloride MMG1 type, provide the necessary current for the loops. In the event of faults on the junction lines, power may be supplied to the loops from the Power Supply at Southwark Fire Station by means of a rectifier.

Fire calls made from the boxes give audible and visual indication at both stations at the same time. The system provides for uninterrupted service in the event of an earth fault or break in the street loops. It also incorporates telephone facilities for the use of the Fire Brigade for communicating between alarm boxes and the Fire Stations.

The equipment at the Superintendent Station at Whitefriars comprises a switchboard, register table, bell and batteries. The switchboard accommodates two fire alarm circuits and is mounted with apparatus and instruments for use in the recording circuit, telephone circuit and battery charge and discharge

circuits. The register table carries a multi-circuit register, time and date stamp with clock, and paper take-up reel.

The Out-Station equipment at Southwark comprises a switchboard, a register table, three gongs and a bell. The switchboard accommodates two fire alarm circuits and carries the apparatus and instruments for use in the recording and telephone circuits as well as the rectifier for emergency purposes. The register table carries three single circuit registers with associated take-up reel, one for normal use, and one spare. The gongs are mounted in the Fire Engine Room and give audible indication of the fire calls. The registers in use are arranged to close circuits for the ringing of call bells in the Firemen's Quarters upon the receipt of fire calls.

Teleprinters.—The use of this type of apparatus is steadily increasing and there are now 250 sets in the Central Telegraph Office.

Stamp Vending Machines.—A number of machines have been installed in the London area at which it is possible to obtain a two shilling book of stamps by the insertion of a florin or two separate shillings.

Traffic Signals.—A new and improved system of traffic signals is being installed in Oxford Street. The telephone apparatus and the lines for both telephones and signals are being supplied by the Post Office. This system will enable a traffic control officer stationed at Oxford Circus not only to supervise traffic at that point from North to South and East to West, but he will also be able to control traffic which enters Oxford Street from side streets between Marble Arch and Tottenham Court Road.

Unique Telephone System.—Dorchester House, a palatial hotel which has been erected near Hyde Park, contains many uncommon features, not least of which is the telephone system. Each room has an extension from the main switchboard for obtaining access to the public telephone system in the usual way, but the telephones are of special design. Each consists of a hand micro-telephone with accommodation for two press buttons. One of these buttons is used to effect direct connection with the service room where the circuit terminates on a special switchboard equipped with lamp signals and an automatic searching device to pick up the calling line. Requests can thus be made without the aid of a P.B.X. operator. When the second press button is depressed a sectional signal and alarm is operated in the service room and at the same time a lamp signal is operated outside the room door in the corridor. This lamp can only be extinguished from inside the room and is effected by a servant inserting an insulated peg which disengages a mechanical lock on a relay.

SCOTLAND WEST DISTRICT.

The conversion of the Ayr and Prestwick Exchanges to automatic working was successfully carried out on the 2nd instant. The installation at both of these exchanges has been installed by Messrs. Ericsson Telephones Ltd.

At Ayr, calling equipment is provided for 1,835 lines with an ultimate of 3,960 lines. At Prestwick the corresponding figures are 560 and 1,260 respectively.

NORTHERN DISTRICT.

The Sixth Annual Dinner of the Middlesbrough Engineering Section was held at the Wellington Hotel, Middlesbrough, on the 14th March. It was a large and representative gathering, the interest and enthusiasm with regard to this function being well maintained. The guests of the evening were Mr. F. G. C. Baldwin, the Superintending Engineer; Mr. B. A. Burton, the Head Postmaster of Middlesbrough and Stockton-on-Tees, and Capt. H. A. Berry, the District Manager, North Eastern Telephone District.

The Chairman—Mr. J. I. Smith, Sectional Engineer—in his opening remarks spoke of the good relations which existed between the various Departments. We were honoured in having as our guests, the Superintending Engineer, the Head Postmaster, and the District Manager. Mr. Baldwin we all know very well, but both Mr. Burton and Capt. Berry were newcomers to the district, and we give them a hearty welcome. He hoped it would not be the last time they would be with us at our annual function.

The Head Postmaster in proposing the toast of "The Post Office Engineering Department," said he had the greatest admiration for the Engineering Department on account of the intricacy and magnitude of its work. He had many friends in this Department, and he was grateful for the opportunity of expressing his appreciation of Mr. Smith and his staff at Middlesbrough who took care that the relationship between the Commercial side and the Technical side was of the happiest, and whether it be telephones, telegraphs, electric lighting, clocks or lifts, if they were in any difficulty one or other of the Engineer's staff was quickly along with the remedy.

Mr. Baldwin, in replying to the toast, spoke of the many changes that had taken place in the Northern District both in the work and in the Staff. He referred to the Engineering achievements, the largest of which was the simultaneous transfer from thirteen Manual Exchanges to twelve Automatic Exchanges in the Newcastle area—this being the largest transfer of its kind ever undertaken in this country. He took this opportunity of expressing personally his thanks to all those in the Middlesbrough Section who had helped to make the transfer a success.

Mr. W. D. Williamson—Chairman of the Middlesbrough Branch of the P.O. Engineering Union—in proposing the toast of "Our Guests" spoke in a few well chosen words of the aim and object for

which not only the Engineering Department, but the other Departments represented by our Guests, were working in unison—the success of that vast undertaking the British Post Office.

Capt. Berry responded to this toast in a very breezy and witty speech. He spoke of the hearty welcome he had received from the people in the North and he felt sure he was going to be happy in his new sphere.

During the evening the Sectional Engineer, on behalf of the Staff, presented a bureau to Mr. W. Tait, who had recently been promoted to a Chief Inspectorship at Coventry---and also a gold watch to Mr. H. Bowron, late Foreman, recently retired.

An excellent musical programme was provided by members of the local staffs.

NORTH EASTERN DISTRICT.

Mr. R. Alexander.

The passing of Richard Alexander on 27th December, 1930, was one of those tragic happenings which reminded us, with unusual force, of the uncertainty of life. He left Leeds early on December 24th and, with his wife and daughter, travelled in his motor-car to Dunbar, where a very happy Christmas was spent in the house to which he intended to remove on his retirement from the service—timed for the latter part of the present summer. During the morning of December 27th he was taken ill but apparently recovered, only to suffer, in the evening, a relapse which culminated fatally in a few minutes.

Mr. Alexander commenced his service in Edinburgh as a S.C. and T., at the age of 15, on 29th October, 1885; later, he took up the study of technical and scientific subjects and the knowledge thus acquired led to his transfer on 1st March, 1898, to a Clerkship in the office of the Superintending Engineer, Mr. James Gibson.

Early in 1903 he was promoted to an Engineership (2nd Class) and proceeded to London where he took up duty in the Estimates Section of the E.-in-C.O. : in those pre-devolution days, the Estimates Section was responsible for a very wide range of estimate scrutiny work, as well as for questions of external plant design and of stores requirements; and those who worked with Mr. Alexander can bear testimony to the big output of work which resulted from the steady and continuous application of his methodical mind to the many problems which arose during the infancy of the " P.O. London Telephone System."

The next promotion came after eight years' service at headquarters, during which period many lasting friendships were formed; and, in February, 1911, Mr. Alexander returned to Edinburgh as Sectional Engineer. He acted in that capacity for 17 years and his ability as an engineer and administrator enabled him to cope successfully with the numerous issues involved, first, in connection with the transfer of the N.T. Co's plant and staff at the end of 1911; secondly, in securing a steady increase in efficiency and a reduction in costs; and, thirdly, in the big task of converting the Edinburgh exchange system from manual to automatic working.

He remained at Edinburgh long enough to see the result of his planning of the auto. transfer work, in the shape of a greatly improved public service; and in August, 1928, he came to Leeds as Assistant Superintending Engineer.

In the last stage of his career, Mr. Alexander displayed the same high qualities as in earlier positions; and he rapidly gained both the respect and the friendship of those new colleagues with whom he came into contact. We parted with him two days before Christmas, knowing that he was contemplating a pleasant interlude in the little town from which, later on, we expected to receive from time to time many friendly messages couched in the humorous strain characteristic of the man : it was not to be, and we mourn the loss of one who, in the short space of two years, had become a real force in the North Eastern Engineering District.

J.W.A.

SOUTH WALES DISTRICT.

Exhibition of Official Films.—The films showing the improved methods of pole hole excavation and cable jointing have been shown at Swansea, Cardiff, Newport, Worcester and Hereford. Keen interest was displayed at all of these places by the workmen, about 400 of whom attended altogether, and Mr. Albry, of the Engineer-in-Chief's Office, was kept busily occupied in answering the inquiries and comments made.

Types of R.A.X. Buildings.—In negotiating for a plot of land on which to erect an R.A.X. it is frequently necessary to meet the wishes of the land owner in regard to the type of building to be erected. For example, in villages in the Cotswold Hills the Department is generally asked to use Cotswold stone for the walls and roof instead of brick and slate. In a case some months ago at the village of Moccas in Herefordshire, in order to harmonise with the local amenities it was decided to erect a " mock " half-timbered building. It is thought that the imitation is an exceedingly good one. The imitation of timbering is effected by a cement band course floated smooth and coated on the top of the rough cast walls and gables.

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS ANNUAL MEETING, 12th MAY, 1931.

THE President of the Institution, Col. Sir T. F. Purves, Engineer-in-Chief, occupied the chair and in opening the proceedings said :—

We have now reached the close of another Session —passed another milestone in the progress of the Institution. For several years I have been making a kind of hobby of calling attention here to the advancement in age of the Institution, and this year I have to announce that it has now completed the full quadrant of its first century since the year of the first session 25 years ago.

Those of you who have been wedded to it since the beginning and done so much by your work and help to further its interests and causes, can look on this meeting as a kind of celebration of your Golden Wedding.

The Annual Report and the Accounts will be placed before you, and I think that, taken in conjunction with several other items of the agenda, it shows that the Institution is not showing any signs of staleness or symptoms of moribundity. It continues to be active and progressive and I am sure it is doing a great educational work—one that is being in a widespread way recognised and appreciated in this country and abroad.

As you all know, the human race still has many years of existence to spend on this earth and it is impossible to know what may be attained. I think, however, that if we could come back in a million years we should find the Institution carrying on and still playing a great and essential part in dealing with problems and subject matter far beyond the reach of our present thoughts or imagination.

However, to-night we are more concerned with the immediate past than with the more or less remote and speculative future.

The first item is the presentation of the Annual Report of the Council.

The Annual Report of the Council was read by the Secretary, Mr. P. G. Hay, and the Financial Statement for year 1930-31 was presented by the Hon. Treasurer, Mr. C. J. Mercer. A resolution that the Annual Report and Financial Statement be accepted was proposed by Mr. T. E. Herbert and seconded by Mr. P J. Ridd. After a statement by Mr. Cruickshank on the satisfactory position of the Journal and a complaint by Capt. Timmis on the time occupied in printing papers, the report and financial statement were adopted. A vote of thanks to retiring Members of Council was proposed by Mr. B. O. Anson, seconded by Mr. C. W. Brown, and replied to by Capt. N. F. Cave-Browne-Cave.

PRESENTATION BY THE PRESIDENT OF MEDALS FOR SESSION 1929-30.

The President then presented the following medals :—

Senior Silver Medal to Mr. A. Morris, A.R.C.Sc., M.I.E.E., for his paper, "Telephone Cable Circuit Interference."

Senior Bronze Medal to Capt. A. C. Timmis, B.Sc., A.M.I.E.E., for his paper, "Carrier Current Telephony."

Junior Silver Medals to Messrs. J. M. Owen, A.M.I.E.E., and J. A. S. Martin, for their joint paper, "Composited Telegraph & Telephone Working."

Junior Bronze Medal to Mr. J. N. Hill, for his paper, "Critical Methods of Investigation as Applied to the Study of Telephone Areas and Plant Lay-out."

An award of £5 to Mr. G. T. Evans in respect of developments in telegraph technique as applied to Radio Circuits (Valve relay), and a joint award of £5 to Messrs. F. I. Ray, B.Sc. (Eng.), A.M.I.E.E., and A. W. Biddlecombe in respect of a new type of relay for use in Automatic Telephone Exchanges, were then given under the terms of the Booth-Baudot Award.

The President announced that Mr. G. F. Greenham and Mr. E. J. Wilby would be respectively Chairman and Vice-Chairman of the London Centre for the session 1931-32.

COUNCIL FOR THE YEAR 1931-32.

The constitution of the Council for the year 1931-32 will be as follows :—

Chairman—Col. A. G. Lee.

Honorary Treasurer—Mr. B. O. Anson.

Representing Staff of the Engineer-in-Chief's Office—Mr. C. W. Brown and Mr. E. S. Ritter.

,, Executive Engineers—
London : Mr. W. C. Burbridge.
Provinces : Capt. H. Hill.

,, Asst. & Second Class Engineers—
London : Mr. J. Prescott.
Provinces : Mr. G. Bailey.

,, Chief Inspectors—
London : *Mr. A. Miller.
Provinces : Mr. W. Weightman.

,, Clerical Staff—
London : Mr. J. T. Kelly.
Provinces : Mr. J. Mawson and Mr. A. C. Smith.

,, Inspectors—
London : Mr. A. E. Donovan.
Provinces : Mr. R. P. Collins.

,, Draughtsmen—
London and Provinces : Mr. F. Downward.

* This representative has since been promoted, and a further election is now proceeding in connection with the resultant vacancy.

ESSAY COMPETITION.

The Judges reported to the Council that the Prize Winners in the recent Essay Competition for the Session, arranged in order of merit, are as follows :

L. F. J. Brunel, S.W. Class II., Guildford. "Modern Aspects of Electricity and Magnetism."

J. C. Alexander, U.S.W., London. "An Introduction to the Electronic Theory and the Conduction of Electricity in Matter."

G. E. Clarke, S.W. Class I., Radio Section, E.-in-C.O. "The Piezo-electric Crystal."

W. E. T. Andrews, S.W. Class II., Cambridge. "Sound and Hearing."

H. Miles, S.W. Class I., Manchester. "The Faultsman and the Subscriber."

The Council decided to award Certificates of Merit to the following four competitors who were next in order of merit :—

A. A. Hard, S.W. Class II., Ipswich. "Insulation in Automatic Areas."

R. N. Renton, S.W. Class I., Circuit Lab., E.-in-C.O. "The Development of A.C. Apparatus in Telegraphy and Telephony."

C. G. Wardrop, U.S.W., London. "Radio Frequency Waves in Space."

W. H. Maddison, U.S.W., Research Section, E.-in-C.O. "The Electron."

The number of essays received this year was 54, an increase of 12 over last year's competition. The Judges reported the quality of the winning essays to be well up to the standard of previous years and the average marking also satisfactory.

PRINTED PAPERS.

The following is a list of the printed papers issued to the Membership during the Session :—

No. 125. "The Development of Automatic Routiners in the British Post Office," A. Speight, A.M.I.E.E.

No. 126. "Telephone Cable Circuit Interference," A. Morris, A.R.C.Sc., M.I.E.E.

No. 127. "Secondary Cells," H. M. Turner.

No. 128. "Critical Methods of Investigation as applied to the study of telephone areas and Plant lay-out," J. N. Hill.

No. 129. "Picture Telegraphy," E. S. Ritter, D.F.H., A.M.I.E.E.

No. 130. "Composited Telegraph and Telephone Working," J. McOwen, A.M.I.E.E., and J. A. S. Martin.

No. 131. "Carrier Current Telephony," A. C. Timmis, B.Sc., A.M.I.E.E.

No. 132. "Heating and Ventilation of Post Offices and Telephone Exchanges," W. T. Gemmell, B.Sc., A.M.I.E.E.

No. 133. "Rural Automatic Exchanges," J. C. Dallow.

The meeting concluded after the reading and discussion on a paper on "Making the Most of Automatic Telephone Apparatus. The Development of Traffic Recording," by W. G. N. Chew.

LOCAL CENTRE NOTES.

NORTH WALES CENTRE.

The sixth and final meeting of the 1930-31 Session was held at Shrewsbury on the 18th March with an attendance of over 70 members. In opening the meeting the Chairman recalled in feeling terms the recent death of the late Superintending Engineer of the North Wales District (Mr. T. Plummer), the members paying the usual token of respect. A fuller note on the loss that the District and the Centre has sustained is written elsewhere.

Mr. R. Sheppard read a lengthy and comprehensive paper on the Birmingham Automatic Scheme. As the transfer of the four initial Exchanges to be dealt with under the proposals had been successfully carried out only a fortnight previously, the subject was eminently topical and the lecturer was able to clothe the bare bones of statistics with the flesh of

personal experience as a result of long and intimate association with the scheme. A keen discussion was prolonged to a late hour and Mr. Sheppard was cordially thanked for his masterly handling of the past, present and future of a subject which will eventually be the largest of its kind in the Provinces.

J.T.W.

SCOTLAND EAST CENTRE.

The Session was opened on the 18th November, 1930, when a paper entitled "Free Wayleaves" was read by Mr. James Patrick. The paper dealt with (1) the conditions under which wayleaves on private property are sought; (2) the measure of success which has attended the efforts made to obtain wayleaves free of payment; (3) the methods in force for recording free wayleaves and (4) the need for safeguarding wayleaves after they have been obtained. An interesting discussion followed.

A paper, entitled "A.C. Rectification for Power Purposes," was read by Mr. R. McWhirter, B.Sc., of the Scotland West District, at the December meeting. The method of converting A.C. to D.C. was explained; various types of rectifiers were discussed, the Tungar rectifier being specially dealt with. The theory and characteristics of dry plate and electrolytic rectifiers; voltage and current relationships between the A.C. and D.C. sides of a rectifier were also dealt with, and reference was made to the Department's requirements. The subsequent discussion brought out some interesting points.

At the January meeting a paper on "Allocations" was read by Mr. J. Airey. The objects of allocation were first pointed out and the importance of the correct allocation of capital and revenue expenditure in business concerns was stressed. The following items as they affected Post Office Engineering expenditure were dealt with :—Budgetary system of control; Capital and Revenue Account; Composite Works; The importance of data on primary vouchers; Adjustment of expenditure. The District expenditure in terms of percentages under the various sub-heads was stated. The paper aroused an interesting and lively discussion, particularly regarding Capital and Revenue expenditure and the accounting methods for surplus and recovered stores.

An informal meeting was held in February where two short papers on the following subjects were read :—"Advice Notes, Motor Transport and Light Construction," by Mr. W. Petrie, and "Drawing Office Records," by Mr. R. A. H. Paterson.

Mr. Petrie dealt with the methods employed in providing subscribers' circuits and carrying out light construction works consequent on the rapid growth of underground plant, the multiplicity of distributing points and the increased motor transport facilities. Other points discussed were the duties of survey men, the size of gangs, suitability of tools, organisation of work, use of motor transport and suitability of vehicles.

Mr. Paterson detailed the various records and the method of preparing them and emphasised the necessity for furnishing correct details with the minimum of delay, and the value of correct and up-to-date records. The need for consulting the standard records before commencing work affecting existing plant was demonstrated.

At the meeting in March the subject of "Development and Underground Relief Schemes," with a discussion on the new T.O.38, was introduced by Mr. H. Burgher. He considered the telephone service to be the cheapest thing sold to-day in the British Isles and that it should be extensively advertised. Too much emphasis was put on the "house" and too little on the possible "subscriber." Important points in the different Sections of T.I.38 were dealt with and suggestions were made with a view to improvements. A number of important points were raised in an interesting and profitable discussion.

The last meeting of the Session was held on the 21st April, when a display of Educational Films illustrated—

(1) The jointing and plumbing of lead-covered cables.
(2) Pole hole excavation by the "bar and spoon" method and "Iwan" earth auger.
(3) Shifting poles by means of pole lifting jacks

Explanatory remarks were offered by Mr. W. H. Albry, who made running comments on the pictures as they were shown.

The new methods brought forth a considerable number of questions and many suggestions were put to the lecturer.

The ordinary attendance was increased by a number of the Department's workmen as well as officials of the Corporation, Railway Companies, Power and Lighting Companies and the Scottish Command.

LOCAL ORGANISATION—1931-2.

Chairman—Mr. J. D. Taylor, M.I.E.E.
Vice-Chairman—Mr. J. T. Tattersall, A.M.I.E.E.
Committee—Messrs. J. A. Gunston, J. W. Jarvis, T. Lawrie, J. McIntosh, R. Ramsay, and W. V. Ryder, M.I.E.E.
Librarian—Mr. T. Lawrie.
Secretary—Mr. J. Airey, Superintending Engineer's Office, G.P.O., Edinburgh.

SOUTH WALES CENTRE.

A visit to Messrs. Lysaghts' Works, Newport, Mon., in October, 1930, inaugurated the meetings of the South Wales District. A large attendance of members under the guidance of one of the Company's Engineers was greatly interested in the various processes of steel plate manufacture.

In November, the second lecture was given by Mr. W. Day, on " Some notes on the conversion of the London Telephonic network from Manual to Director Working." The lecture was illustrated by lantern slides. Opportunity was taken at this meeting to congratulate Mr. H. J. Hunter, late Sectional Engineer, Newport, on his promotion to the position of Assistant Superintending Engineer at Cardiff.

The third lecture in December was given by Mr. E. A. Pearson, on " Waste, with general reference to Engineering work and Design." Mr. Pearson's paper dealt with the question of economy in the cost of production and showed that the elimination of waste, whether of money, material or labour, was the greatest need of all staple industries to-day.

The fourth paper given by Mr. S. G. Joscelyn, Swansea, on " The Drawing Office and its Functions," dealt with the place and functions of the Drawing Office in Engineering work generally, and reviewed in detail the application of these to the particular case of the Post Office Engineering Department.

The fifth paper was jointly given by Messrs. R. D Fuse and A. E. Tiley on the subject of " R.A.X's." Mr. Fuse dealt with the constructional side of the subject and from his expert and practical knowledge uch valuable information was obtained. Mr. Tiley then dealt with the equipment details. Many lantern slides were shown of R.A.X. buildings installed in various parts of the District.

The last lecture of the series was given by Mr. H. C. A. Linck and was entitled " The Construction and Operation of Teleprinter 3A." Apparatus was installed in the Lecture Theatre and a practical demonstration was given of the working of Teleprinters.

THE INSTITUTION OF P.O. ELECTRICAL ENGINEERS.

Officers of Colonial and Foreign Telegraph Administrations who are engaged in Electrical Engineering Works may be admitted as Colonial and Foreign Corresponding Members respectively, after application.

Subscription payable annually in advance on 1st April in each year :

Colonial Members	... ...	£1 0 0
Foreign ,,	... ...	£1 10 0

These sums include Annual Subscription to the Journal of P.O. Electrical Engineers and the supply of all Professional Papers issued during the period covered by subscription.

Forms of application for Colonial and Foreign Membership can be obtained on application to

The Secretary,
Institution of P.O.E. Engineers,
G.P.O. (Alder House), E.C.1,

or the undermentioned gentlemen who have kindly agreed to act as representatives of the Institution in their respective countries :—

R. Badenach, Esq., B.Sc. (Melb.),
Chief Engineer's Office,
Postmaster-General's Department,
Treasury Gardens,
Melbourne, C.2,
Australia.

H. C. Brent, Esq.,
District Telegraph Engineer's Office,
Wellington, N.Z.

N. N. Banerjee, Esq., A.M.I.E.E. (Ind.),
Divisional Engineer, Telegraphs,
Calcutta West Division,
8, Wellesley Place,
Calcutta,
India.

A. T. Kingston, Esq., M.B.E., A.M.I.E.E.,
Office of the Chief Engineer,
Telegraphs & Telephones,
C.T.O.,
Colombo,
Ceylon.

A. J. Kellaway, Esq.,
Department of Posts and Telegraphs,
P.O. Box 366,
Pietermaritzburg,
South Africa.

E. L. Jephcott, Esq., A.M.I.R.E.,
Chief Engineer's Department,
G.P.O. Box 391,
Salisbury,
South Rhodesia.

BOOK REVIEWS.

" High Frequency Alternating Currents." By Knox McIlwain and J. C. Brainerd. (London: Messrs. Chapman & Hall). 510 pages. Price 30/- net.

The subject matter of this book outlines a course designed for senior or first year graduate students in electrical communications and, as such, has been given for the past several years to students at the Moore School of Electrical Engineering, University of Pennsylvania.

A knowledge of the calculus, some familiarity with differential equations and acquaintance with the elementary theory of alternating currents, including the use of complex numbers, is assumed.

The term " high frequency " is used in this book to designate any frequency used in telephony and sound reproduction, in carrier telegraphy and telephony, and in radio telegraphy and telephony.

The following is a brief summary of the contents. In an introduction the nature of sound and the requirements to be considered in its transmission are discussed. Carbon granule and condenser transmitters, telephone receivers, loud speakers and the transmission unit are dealt with in the first chapter. Separate chapters are then devoted to resonance phenomena, coupled circuits, thermionic vacuum tubes, amplification, modulation, detection, production of high frequency currents, filters, transmission lines, electromagnetic waves, reflection and refraction, electro-mechanical systems.

Although the authors lay no claim to an exhaustive treatment of the subject, a large amount of information is nevertheless given on each particular section.

The material included and the method of presentation has been chosen with a view to its suitability for students in electrical engineering and in this the authors have been very successful.

The book is well illustrated with curves and diagrams and at the end of each chapter a bibliography, bearing upon the subject dealt with in that chapter, is given.

Included in each chapter are a number of problems which are intended to be solved by the student.

The book can be recommended to students in electrical communications and it should also prove very useful to engineers.

G.W.H.

" Elementary Technical Electricity." By L. T. Agger, B.E. 268 pps. (Published by Longmans, Green & Co.). Price 3/6.

This little book is intended to meet the needs of first year electrical students in evening Technical Schools and, although it does not cover the whole of the City and Guilds syllabus in Magnetism and Electricity, it should prove useful to students preparing for this examination. After a preliminary survey of elementary Mechanics, the author deals with Magnetism, the effects of an electric current, primary and secondary cells, ending with a short account of electro-magnetic induction. The exercises given at the end of each chapter have been carefully chosen and form a useful feature.

W.S.P.

" Corso di Telefonia: Part 1; Telephone Apparatus." By Ing. Dott. Scipione Treves. (Sten: Turin). 35 Lire.

The rapid development in Italy, during recent years, of modern telephone communication has stimulated the interest of Italian engineers, technicians and teachers of physical science in the art of modern telephony and the author of the present volume is to be congratulated on having produced the first part of what is almost certain to become the standard Italian text-book on the subject. The whole subject is to be covered in three volumes. The present volume deals mainly with subscriber's station equipment, including protective devices, prepayment, and intercommunicating systems. Sufficient theory is included and practical consideration in regard to installation, maintenance and testing receive ample treatment. The diagrams and illustrations, of which there are many, are uniformly clear and distinct. Naturally, the type of apparatus and the practices described are those in current use in Italy. Part 2 will deal with Telephone Lines and Networks and Part 3 with Telephone Exchanges.

J.J.M.

STAFF CHANGES.

POST OFFICE ENGINEERING DEPARTMENT.

PROMOTIONS.

Name.	From	To	Date.
Hart, A. B.	Staff Engineer, E.-in-C.O.	Assistant Engineer-in-Chief.	1-7-31
Hines, Capt. J. G.	Assistant Suptg. Engineer, London District.	Staff Engineer, E.-in-C.O.	1-7-31
Blick, F.	Executive Engineer, E.-in-C.O.	Assistant Suptg. Engineer, London District.	1-7-31
Cottle, Maj. P. J., O.B.E., M.C.	Assistant Engineer, S. West District.	Executive Engineer, S. West District.	1-4-31
Bell, R. L.	Assistant Engineer, E.-in-C.O.	Executive Engineer, E.-in-C.O.	1-4-31
Chamney, R. M.	Assistant Engineer, E.-in-C.O.	Executive Engineer, E.-in-C.O.	To be fixed later.
Noyes, H. S.	Assistant Engineer, E. District.	Executive Engineer, E. District.	16-3-31
Albry, W. H.	Assistant Engineer, E.-in-C.O.	Executive Engineer, Testing Branch Birmingham.	1-4-31
White, A. E.	Assistant Engineer, S. Lancs. District.	Executive Engineer, S. Lancs. District.	16-3-31
Jeary, L. G.	Assistant Engineer, Scot. West. District.	Executive Engineer, S. Lancs. District.	7-4-31
Dipple, H. W.	Assistant Engineer, E.-in-C.O.	Executive Engineer, E.in-C.O.	1-6-31
Stevenson, B. J., O.B.E.	Assistant Engineer, E.-in-C.O.	Executive Engineer, E.in-C.O.	1-4-31
Paish, P. B.	Chief Inspector, S. East District.	Assistant Engineer, S. East District.	To be fixed later.
Veale, A. H.	Chief Inspector, London District.	Assistant Engineer, E.-in-C.O.	To be fixed later.
Miller, A.	Chief Inspector, London District.	Assistant Engineer, London District.	To be fixed later.
Little, W. R.	Chief Inspector, London District.	Assistant Engineer, London District.	To be fixed later.
King, A. G.	Chief Inspector, S. Mid. District.	Assistant Engineer, S. Wales District.	To be fixed later.
Dunk, W. G.	Chief Inspector, E.-in-C.O.	Assistant Engineer, E.-in-C.O.	1-4-31
Cresswell, W. H.	Chief Inspector, E.-in-C.O.	Assistant Engineer, E.-in-C.O.	To be fixed later.
Meldrum, F. A.	Chief Inspector, E.-in-C.O.	Assistant Engineer, S. Lancs. District.	To be fixed later.
Wilson, C. F.	Repeater Officer, Cl. II., E. District.	Chief Inspector, E.-in-C.O.	22-3-31
Pirie, H. A.	Repeater Officer, Cl. II., E. District.	Chief Inspector, E.-in-C.O.	22-3-31
Wood, Capt. J. A., M.C.	Repeater Officer, Cl. II., S. Wales District.	Chief Inspector, E.-in-C.O.	1-9-30
Robinson, R. P.	Chief Inspector, E.-in-C.O.	Assistant Engineer, E. District.	To be fixed later.
Davies, L.	Inspector, N. Wales District.	Chief Inspector, N. Wales District.	To be fixed later.
Collins, T. J.	Inspector, S. Mid. District.	Chief Inspector, S. Mid. District.	
Bryant, G. H.	Inspector, S. East District.	Chief Inspector, S. East District.	
Davidson, T.	Inspector, N. District.	Chief Inspector, Scot. W. District.	
Heaton, A.	Inspector, S. Lancs. District.	Chief Inspector, S. Lancs. District.	
Howcroft, A.	Inspector, N. East District.	Chief Inspector, N. West District.	
Bolton, G. F.	Inspector, S. Mid. District.	Chief Inspector, S. Mid. District.	
Layton, N.	Inspector, London District.	Chief Inspector, London District.	15-2-31
French, W. S.	Inspector, N. Ire. District.	Chief Inspector, N. Ire. District.	16-8-30
Sims, A. E.	Inspector, E.-in-C.O.	Chief Inspector, E.-in-C.O.	To be fixed later.
Carr, G. E.	Inspector, E.-in-C.O.	Chief Inspector, E.-in-C.O.	
Downes, A. D. W.	Inspector, Testing Branch.	Chief Inspector, Testing Branch.	
Bevis, W. F.	Repeater Officer, Cl. II., E. District.	Chief Inspector, E.-in-C.O.	
Leece, W.	Skilled Workmen, Cl. I., N. District.	Inspectors, N. District.	17-2-31
Grant, C.			15-3-31
Mickler, L.			28-12-30
Mellish, A.	Skilled Workmen, Cl. I., Scot. W. District.	Inspectors, Scot. W. District.	27-11-30
Hutton, R.			23-11-30
McCullough, J.			25-3-31

PROMOTIONS—*continued.*

Name.	From	To	Date.
Bogg, A.	Skilled Workman, Cl. I., E.-in-C.O.	Inspectors, E.-in-C.O.	16-11-30
Voss, L. C.	Skilled Workman, Cl. II., E.-in-C.O.		1-1-31
Hay, J.	Skilled Workman, Cl. II., E.-in-C.O.		1-1-31
O'Roark, A. F.	Skilled Workman, Cl. II., N. Wales District.	Inspector, N. Wales District.	13-7-30
Strathern, J.	Skilled Workman, Cl. I., Scot. W. District.	Inspector, Scot. W. District.	19-4-31
Stokes, B. C.	Skilled Workman, Cl. I., S.W. District.	Inspector, S.W. District.	11-2-29
McClarnon, J. R.	Skilled Workman, Cl. I., N. Ire. District.	Inspector, N. Ire. District.	27-5-30
Smith, W. C.	Skilled Workman, Cl. I., Scot. W. District.	Inspector, Scot. W. District.	19-2-31
Hogarth, R. N.	Skilled Workman, Cl. I., Scot. W. District.	Inspector, Scot. W. District.	13-4-31
Speight, E. A., Ph.D.	Unest- Skilled Workman, E.-in-C.O.	Inspector, E.-in-C.O.	To be fixed later.
Brogden, A. E.	Skilled Workman, Cl. I., N.E. District.	Inspector, E.-in-C.O.	To be fixed later.

APPOINTMENTS.

Name.	From	To	Date.
Knight, N. V.	Limited Competition.	Probationary Inspectors.	1-5-31
Turner, A. F.			
Prescott, J.			
Goodchild, R. F.			
Atkinson, J.			
Harnden, A. B.			
Nickolls, C. A. L.			
Owens, W. H.			
Renton, R. N.			
Dunn, W. K.			
Prickett, W.			
Carrette, A. D.			
Hamilton, D. F.			
Stonebanks, A. M.			
Judson, J. E.			
Porter, W. F.			
Watling, C. E. G.			
Fairs, A. E.			
Ellendon, A. H.			
Pilcher, C. J. F.			
James, L. R.			
Combridge, J. H.	Open Competition.	Probationary Inspectors	
Mayne, E. A.			
Fogg, G .H.			
Trott, L. J.			
Button, G. E.			
Reed, R. E.			
Leach, F.			
Edwards, S. J.			
Pugh, S. E.			
Dolan, W. H.			
Maddison, W. H.			
Watson, L. R.			

RETIREMENTS.

Name.	Rank.	District.	Date.
Shaughnessy, E. H., O.B.E. ...	Assistant Engineer-in-Chief.		30-6-31
Bailey, W. J.	Staff Engineer.	E.-in-C.O.	31-5-31
Markwick, J. J.	Assistant Staff Engineer.	E.-in-C.O.	30-4-31
Cheshire, F. W.	Assistant Suptg. Engineer.	Eastern.	31-3-31
Brown, J.	Assistant Suptg. Engineer.	London.	30-6-31
Bannister, G. W.	Executive Engineer.	S. West.	31-3-31
Chambers, H. M.	Assistant Engineer.	London.	31-3-31
Vaughan, G. H.	Assistant Engineer.	S Lancs.	28-2-31
MacLean, M. J.	Chief Inspector.	Scot. West.	19-3-31
MacKenzie, K.	Inspector.	Scot. West.	12-4-31
Wilshen, H. G.	Inspector.	London.	31-3-31
Edwards, F.	Inspector.	N. West.	14-6-31

DEATHS.

Name.	Rank.	District.	Date.
Coward, C.	Chief Inspector.	N. West.	8-5-31
Gough, H. H.	Inspector.	S. Lancs.	7-2-31
McEwan, J.	Inspector.	Scot. West.	2-5-31
Husband, W. J.	Inspector.	London.	6-3-31

COLONIAL APPOINTMENTS.

Name.	Rank and District.	To	Date.
Graham, C.	Assistant Engineer, S. Lancs.	Palestine.	1-4-31
Millar, H. T. W.	Assistant Engineer, E.-in-C.O.	Egypt.	19-6-31

CLERICAL ESTABLISHMENT.

RETIREMENTS.

Name.	Rank.	District.	Date.
Crossley, W. C.	H.C.O.	S. Lancs.	12-4-31
Payne, W. J. A.	H.C.O.	L. E. D.	30-4-31
Gell, E. R.	Executive Officer.	L. E. D.	12-6-31
Brockett, A. W.	H.C.O.	L. E. D.	30-6-31
Harmsworth, W. H.	H.C.O.	S. Eastern.	26-6-31

PROMOTIONS.

Name.	From	To	Date.
Tyson, J.	H.C.O. (Scot. East).	Staff Officer (Scot. W.)	1-4-31
Donaldson, J. G. K.	Clerical Officer (N. Wa.)	H.C.O. (N. Wales).	11-4-31
Willcock, H.	Clerical Officer (S.Lcs.)	H.C.O. (S. Lancs.)	13-4-31
Swan, R. K.	Clerical Officer (Scot. E.)	(H.C.O. (Scot. E.)	1-4-31
Sells, W. E.	Clerical Officer (L.E.D.)	H.C.O. (L.E.D.)	1-5-31

DEATH.

Name.	Rank.	From	Date.
Golding, F.	H.C.O.	North Wales.	10-4-31

TRANSFERS.

Name.	Rank.	From	To	Date.
Williams, J. T.	H.C.O.	Oxford.	Croydon.	27-6-31

BOARD OF EDITORS.

B. O. ANSON, M.I.E.E., Chairman.

P. J. RIDD, M.I.E.E.

H. KITCHEN, M.I.E.E.

A. J. GILL, B.Sc., M.I.E.E., M.I.R.E.

J. D. BOULTON.

J. T. KELLY.

W. CRUICKSHANK, M.I.E.E., Managing Editor.

J. J. MCKICHAN, O.B.E., A.M.I.E.E., Assistant Editor.

COMMUNICATIONS.

All Remittances and Communications should be addressed to the MANAGING EDITOR, P.O.E.E. JOURNAL, Engineer-in-Chief's Office, Alder House, London, E.C.1.

Binding covers and copies of the Contents for Vol. 3 to 23 are available, and may be obtained from the local agents for 1*s.* 6*d.* and 3*d.* respectively. Subscribers can have their copies of Vol. 23 bound, with index included, at a cost of 3*s.*, by sending the JOURNALS to the local agents. Orders for bindings, Vols. 1—19, should indicate whether the original binding with black lettering, or the latter pattern in gold, is required. Covers with gold lettering will be the only type stocked from Vol. 20 onwards.

The price of the JOURNAL is 1*s.* (1*s.* 3*d.* post free) per copy, or 5*s.* per annum, post free. All back numbers 2*s.* each.

THE
Post Office Electrical Engineers' Journal

"DEMAND" TRUNK SERVICE.

I. H. Jenkins, M.I.E.E.

THE British Post Office has recently decided to reorganise its Trunk service with the object of effecting communication as nearly as possible on a demand basis. The purpose of this article is to outline the work involved in providing the necessary equipment and to indicate, in a general way, the trend of design which is being adopted for the switchboard equipment.

Calls which involve recording on tickets for accounting purposes, as hitherto operated in Great Britain, fall into two categories: those known as Toll Calls, and those known as Trunk Calls. Toll calls are completed normally on demand by an "A" operator or by a Toll operator to which the subscriber is immediately connected. The area around London represented by the South Eastern corner of England, enclosed by an arc struck approximately from Southampton, through Newbury, Cambridge and Ipswich, forms the most important toll area, in which the calls are completed on a no-delay basis immediately a demand has been received from the subscriber. A similar service exists between the Liverpool and Manchester areas and between the Edinburgh and Glasgow areas. Calls made over the longer distances, for example between the London area and the Manchester area, are known as Trunk calls. These calls have been handled on what is known as the trunk basis, that is, the subscriber is connected to a record operator, who records the call on a ticket which is passed to an operator in charge of the trunk lines concerned and completed by her when the trunk line is available, the calls being dealt with in code time order. The objective aimed at in reorganising the trunk service is the immediate completion of calls on demand, similarly to Toll calls, without the necessity of the subscriber having to hang up his receiver and be recalled. This service is known in the British Post Office as the Demand Trunk Service.

Trunks have been operated on the basis of assigning to each operator a small number of trunk lines, these lines being terminated at each end on a single jack and calling signal. It is the duty of the operator to pass as many calls, represented by tickets, as possible over the lines under her charge. This might be described as a "line" basis of operating. In "On Demand" operating, the operator in the Trunk exchange will make out the ticket and immediately proceed to set up the connection. She also makes all enquiries which may be necessary to effect the connection and satisfy the caller. This might be described as a "call" basis of operating.

The demand operator must be in a position to spend as much time as necessary in handling the call; some form of traffic distribution must therefore be provided for incoming calls from subscribers requiring trunk connection. She must also have access to all available trunks, both on direct and alternative routes, to the point to which the trunk call is required.

The supervisory signal in the cord circuit must be controlled by the calling subscriber, and the connection held by the operator whether from a manual or an automatic exchange. It will also be necessary for the demand operator to be able to ring the subscriber, so as to hold his line in case of delay in setting up a trunk connection.

In order to give full availability over the trunk network to all operators, trunks will work bothways and be multipled on incoming trunk positions for through connections, as well as on demand positions.

Under the present method of line operating, trunks are provided on a basis of a maximum of 15

minutes delay in the busy hour. It is anticipated that a "demand service" can be given on this plant of the order of 72% of calls completed within 1½ minutes, 12% within 10 minutes, the remainder being of a more difficult nature, due to unusual circumstances such as the wanted subscriber being unavailable. The improvement in service will be entirely due to the methods of operating and the availability of alternative routes.

directly connected to the zone centres for access to the trunk network. The devolution of control will facilitate routing of the call by direct lines wherever traffic warrants it, and also facilitate the provision of the signalling and ringing facilities previously referred to.

Existing trunk plant, designed for operating on a line basis with separate recording positions, is entirely unsuitable for demand service, and it has

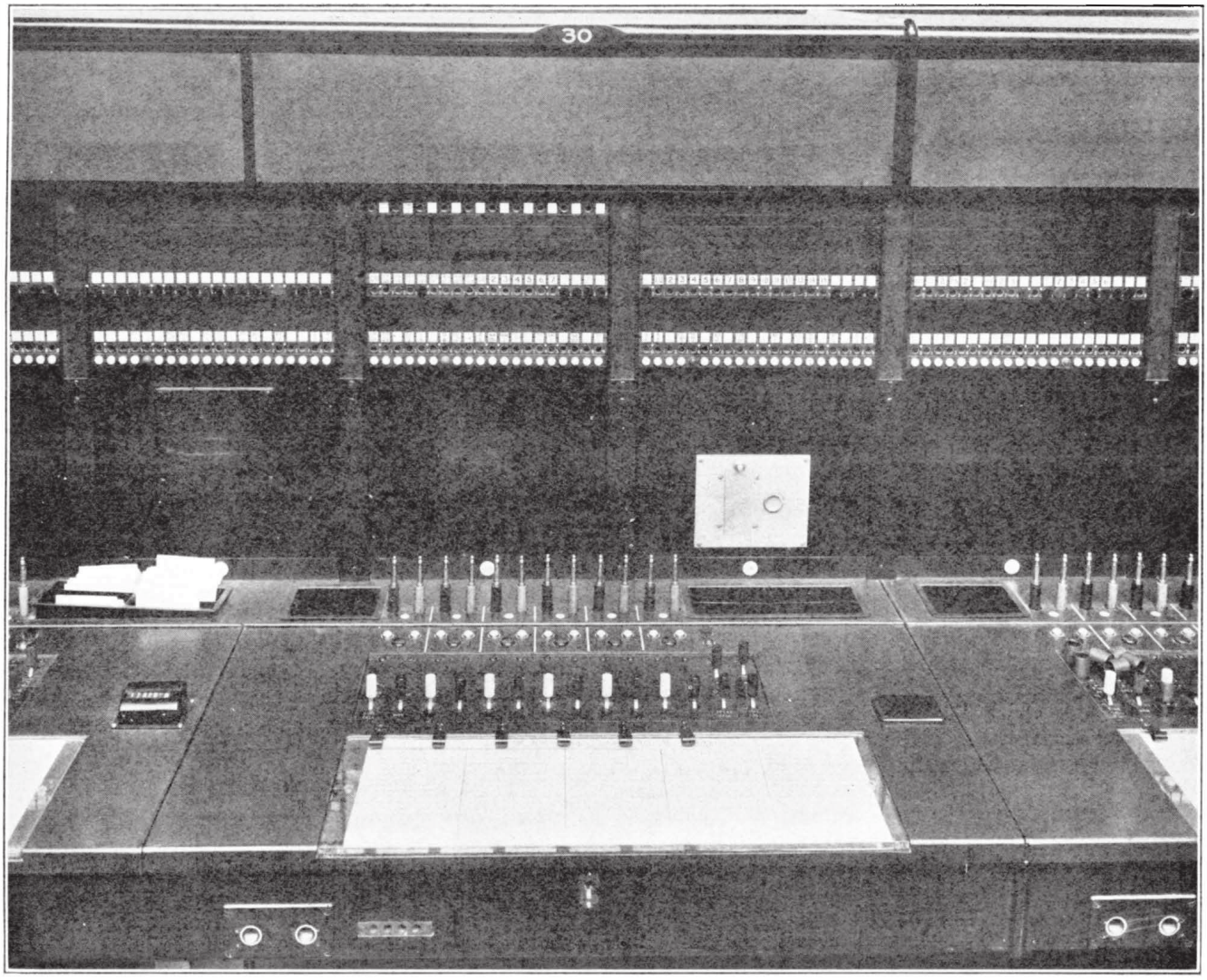


FIG. 1.—KEYBOARD AND JACK PANELS, NEW TYPE TRUNK SWITCHBOARD.

Repeater cord circuits will, wherever possible, be replaced by terminal repeaters associated with the trunk lines to simplify operating and to avoid risk of low grade transmission due to repeater cords being omitted when setting up a call.

Hitherto, trunk calls have been controlled in zone centres of which there are about twelve in the British Isles. Under the reorganisation, trunk calls will also be controlled at group centres which will be

been necessary to design entirely new circuits and a new type of switchboard section.

The switchboard section is of the type usual in manual exchanges, but accommodates the large type jack commonly used in British Post Office No. 10 Exchanges. Seven panel sections giving a twenty-seven inch wide position will be employed. The keyboard is of ample width to provide bulletin and writing space. Fig. 1 illustrates the keyboard and

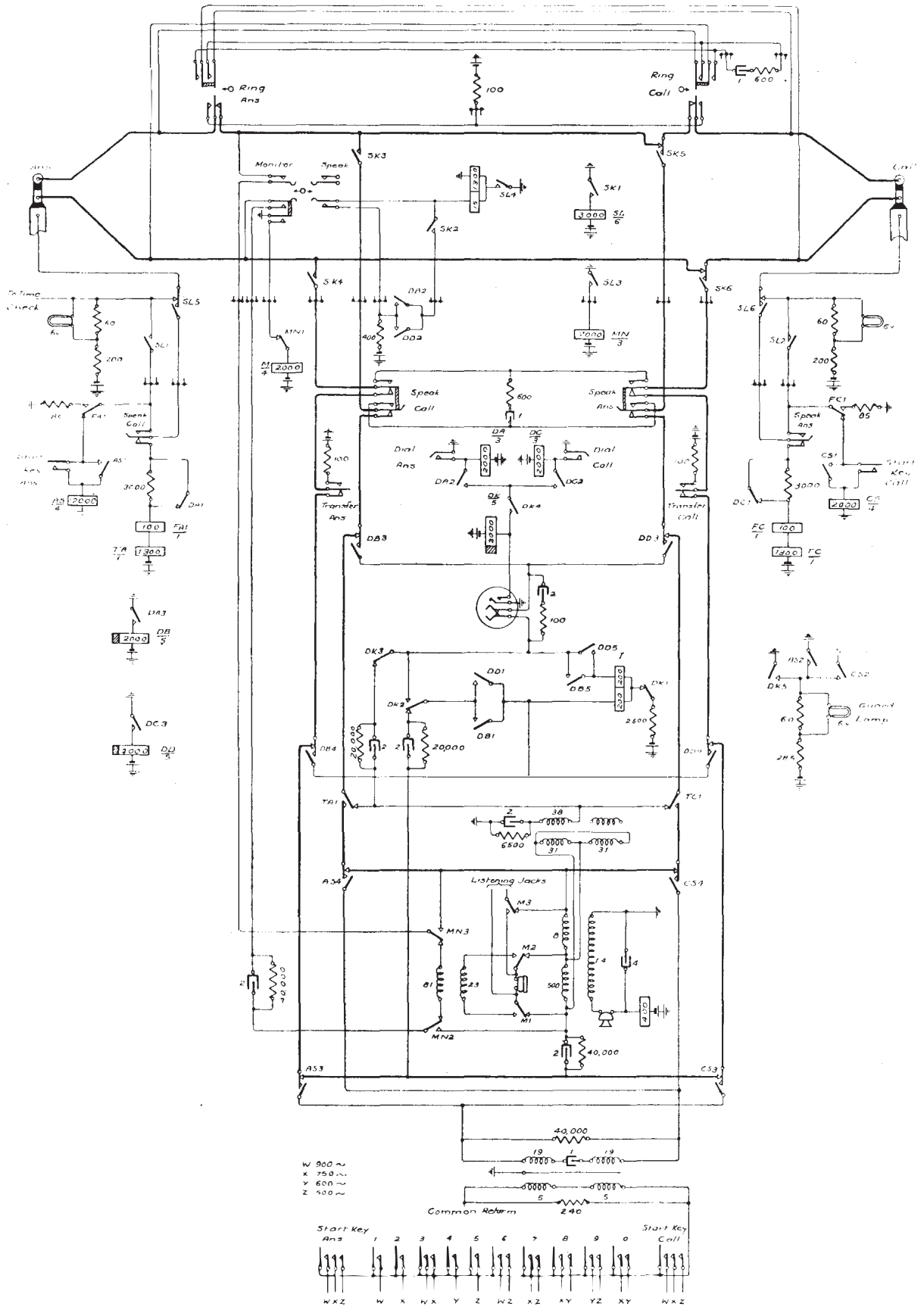


FIG. 2.—CORD CIRCUIT AND POSITION EQUIPMENT.

jack panels; it is from a photograph of a low section designed for a special case.

The cord circuit is of the sleeve control type, the signalling being effected over the third conductor from terminal equipment associated with the lines. No bridging or other apparatus, except ringing and speaking keys in connection with the talking conductors of the cord, will be necessary.

Answering jacks and calling lamps, for both the demand lines carrying originating trunk traffic and incoming trunk lines, will be multipled in order to provide for traffic distribution. In the larger exchanges this multiple may consist of as many as twenty appearances giving access to some forty operators.

Outgoing trunk multiples will be provided with idle trunk indicators, consisting of multipled lamp signals indicating an available trunk in the group. On this trunk being taken up by an operator, the signal will move automatically to another idle trunk. This signal is of a new type and consists of placing the lamp behind a translucent number plate instead of the practice hitherto employed of using a separate lamp jack and designation strips. The adoption of the idle trunk scheme, as compared with the older practice of visual engage signalling, will very materially reduce current consumption and, what is more important, heating, which arises from a large number of lamps alight simultaneously in a multiple jack field.

The cord and position equipment is shown in Fig. **2** and typical terminal equipment in Figs. **3** and **4**. In the normal condition, without keys thrown, the cord circuit consists simply of straight through conductors from plug to plug with a lamp connected from battery to each plug sleeve. These lamps are controlled by means of a double wound third conductor relay in the line terminal equipment, the high resistance winding being short-circuited when a clearing signal is received, by the line relay allowing sufficient current to flow to light the lamp.

Throwing the cord circuit speaking key operates relays SK and SL. Relay SK operates in series with 400 ohms initially through its 1300 ohm winding, which is immediately short-circuited by relay SL. This arrangement prevents more than one SK relay being operated simultaneously and is to prevent more than one cord circuit being connected at the same time to the position equipment. The contacts of relays SK and SL split the talking and sleeve conductors of the cord and carry the two plug and lamp circuits separately into the position equipment. All necessary facilities such as tertiary busy test, dialling, key sending and disconnecting either side of the line circuit for challenging purposes are provided in the position equipment.

The sleeve circuit, when carried into the position equipment, is disconnected from the lamp and spools of about 240 ohms and taken to battery through relays of 1400 ohms resistance. This change in resistance is utilised to operate a relay in the terminal equipment when required for releasing ringing relays or other purposes. The relay DR shown in Fig. **3** is differentially wound; the currents flowing in each of the two windings are opposed to each other and are approximately equal when the cord circuit speaking key is normal. When thrown, the current in one winding is increased sufficiently to operate the relay.

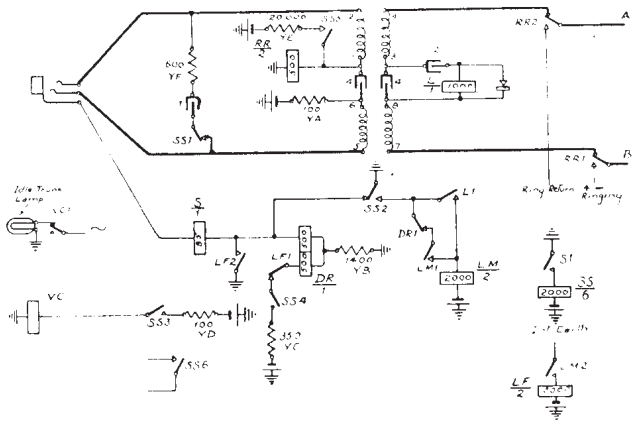


FIG. 3.—LINE EQUIPMENT FOR OUTGOING MANUAL RING-DOWN TRUNK.

When no speaking key on the position is thrown, the monitoring key taps the cord through a high impedance transformer with the operator's transmitter disconnected, but when any speaking key is thrown all monitorings keys function as speaking keys.

The terminal equipments on lines working on manual ring-down principles are designed to flash the cord circuit lamp when a ring is received from the distant end. Relay LF (Fig. **3**) is flashed when relay LM is locked up, relay LF disconnects battery from relay DR and applies earth to relay S. If the cord circuit speaking key is thrown, DR will operate during the flash interval and release LM.

Lines working on CB signalling principles will, when the distant end clears, cause the cord circuit lamp to glow continuously. (See Fig. **4**). Relay

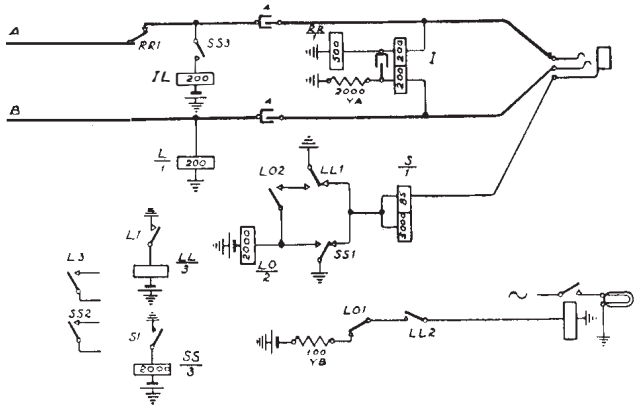


FIG. 4.—LINE EQUIPMENT FOR INCOMING C.B. SIGNALLING TRUNK.

LO is, however, provided to lock out the calling signal until the distant end clears should the trunk exchange take down the connection first.

Voice frequency key sending, intended in this design for use on short CB signalling trunks or junctions, is controlled automatically on principles similar to regular CB junction signalling. On the depression of the start key, relay CS in Fig. **2** operates and locks itself in; it also connects the digit key strip to line and lights the guard lamp. The line equipment will be somewhat similar to Fig. **4**. The L relay in the terminal equipment will remain operated until the sender at the distant end has stored all the digits sent out and for which it is designed. The L relay then releases until the called subscriber has answered. The release of L will operate FC in Fig. **2** and in turn release CS.

Dialling conditions are set up by throwing a locking key in the position equipment. By means of relays DC and DK in conjunction with the arrangements in the line terminal equipment, not shown in this article, the dial is connected directly in series with the line so long as the dialling key remains thrown or the dial is off normal. Relays SK and SL are also held under these conditions to avoid risk of clipping the last train of impulses should the operator prematurely replace the speaking key.

Fig. **5** shows the connection of multipled calling lamps. Six volt lamps are being used, and these are wired on a three-wire scheme to avoid excessive voltage drop and the risks of signal failure should a lamp become short-circuited. The lamps will give satisfactory signals over a very wide range of voltage. They will be lit with raw AC transformed off the supply mains. Relay LC and the transformer will be mounted near the end of the switchboard suite to avoid the necessity for installing heavy wire which would be required for long low voltage leads.

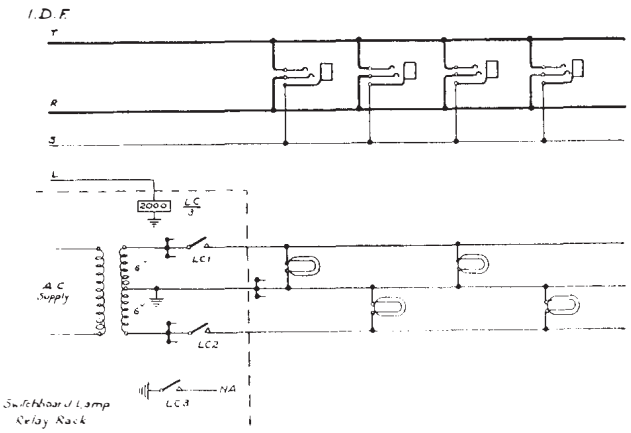


FIG. 5.—MULTIPLED CALLING LAMPS.

Sixty positions have been installed and are in service at the London Trunk Exchange built to designs indicated in this article. New equipment is in hand for Birmingham, Leeds, Liverpool, Manchester, Newcastle and other Zone centres. Development is proceeding on the basis of the design outlined to meet the different conditions which arise both in the Zone trunk exchanges and in the various types of exchanges concerned in the group centres.

ACORN EXCHANGE.

" Great things from little Acorns grow,
And though the progress may seem slow,
Yet wise men have been known to say
That Rome was not built in a day;
And what is Rome compared to this
Full mechanised Telephonist."

PROGRESSIVE INSTALLATION OF THE NEW STANDARD OPEN TYPE RACKS AND SHELVES.

B. HOUGHTON BROWN,

Engineering Division, Standard Telephones and Cables, Limited.

THE preceding articles in this series have dealt with stages 1 and 2 in the progressive installation of Acorn Exchange, and we are now left with the third and final stage consisting of shipping and placing the apparatus in position on the shelves.

Before detailing the method of handling the apparatus, it is thought that a brief outline of the changes which have been made to the Acorn Exchange lay-out, due to the improved method of dealing with the order wire junction traffic and to the growth of automatic routine testing, would be of interest.

Fig. **16** shows the manual room carrying the traffic for Acorn, Southall and Perivale Exchanges, and it is here that one of the biggest changes in

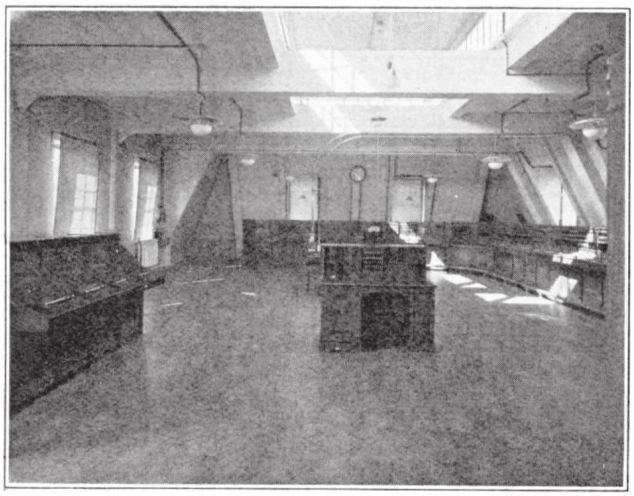


FIG. 16.—MANUAL ROOM.

lay-out has taken place due to the reduction in the number of " B " operators' positions, as indicated by the gap in the line up, consequent on the order wire traffic being handled on a 4-frequency signalling basis.

Conversely, as the number of " B " positions has been reduced, so additional 4-frequency signalling relay sets have been added to the automatic apparatus room.

Automatic routing is another item which has received a considerable amount of attention, and its growth has been responsible for changes both in cabling and lay-out, all apparatus, with the exception of the uniselectors, now being automatically tested except in cases where the quantities are not sufficient to warrant the added expenditure. The following routiner racks have been installed at Acorn :—

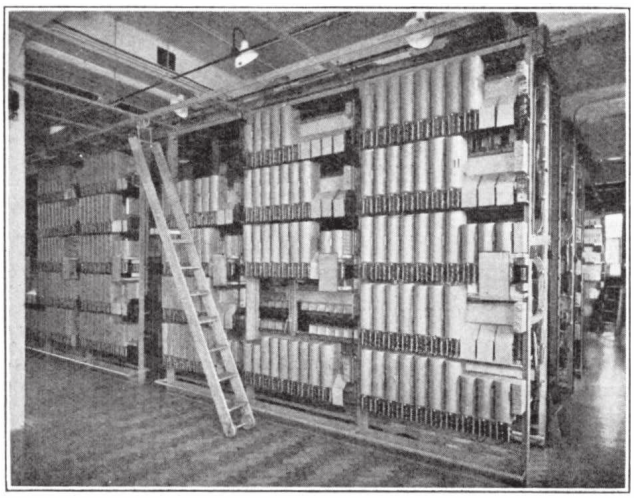


FIG. 17.—FINAL SELECTOR RACKS.

1. Sender routiner.
2. Outlet relay set routiner.
3. Auto and C.C.I. junction routiner
4. C.C.I. relay set routiner.
5. 1st code selector routiner.
6. Coder routiner.
7. Director routiner.
8. Junction relay set routiner.
9. Regular and P.B.X. final routiner
10. 4-frequency routiner.

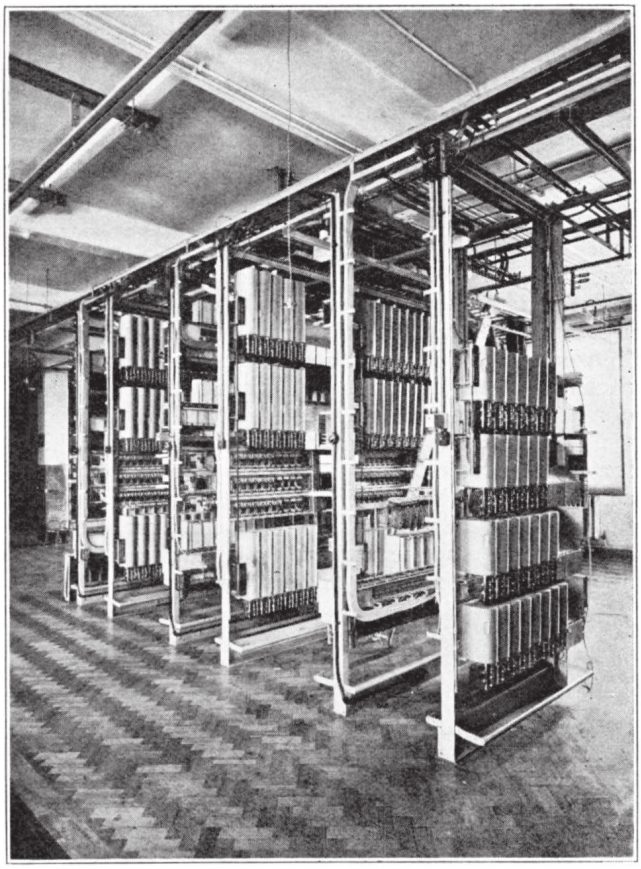


FIG. 18.—FIRST CODE AND A DIGIT RACKS.

These features, *i.e.*, 4-frequency signalling and routiner testing, represent two of the latest developments in automatic telephony, and their introduction should have far reaching effects in improving the general performance of exchange working.

The previous issue of this bulletin left us with the racks and shelves fully erected and cabled, with the banks held in position by temporary bank supports awaiting the arrival of the switches, and we will now show, by means of a series of photographs, how these switches have been mounted in position, and how the channel shelf has been adapted to all types of selectors and relay sets.

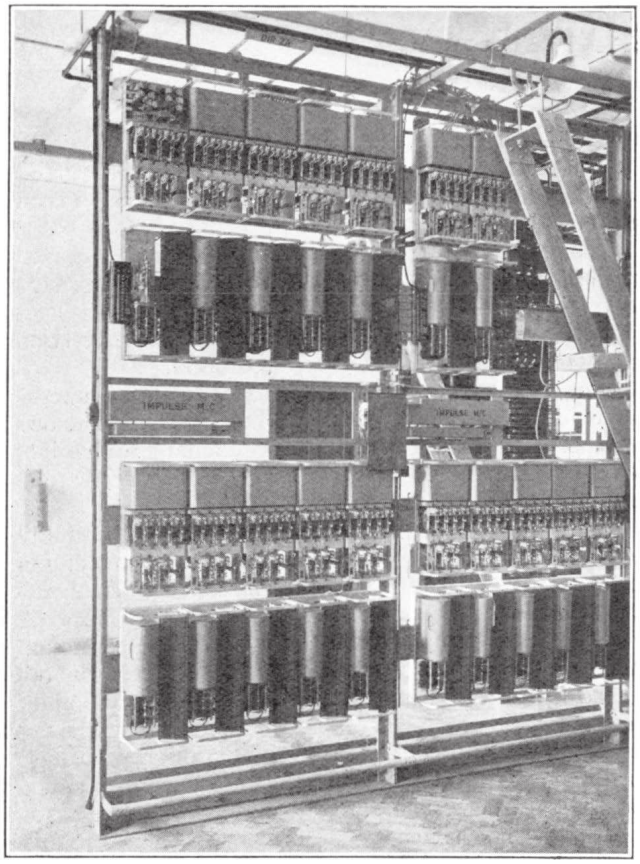


FIG. 19.—DIRECTOR RACK.

Fig. **17** shows the final selector rack fully equipped and should be compared with Figs. **5**, **6**, and **15** in the previous issues of this Journal, when the four distinct stages of installation will be seen, *i.e.* :

1. Framework erected.
2. Cables run in position.
3. Shelves erected.
4. Switches mounted in position.

Fig. **17** also shows the rack grading charts mounted on the right hand side in the centre of the rack. These charts are carried on hinged brackets enabling them to be swung out at right angles to the rack, thus ensuring accessibility to all switches.

Switches controlling the flood lights can be seen mounted on the end of the racks down the right hand gangway.

Fig. **18** includes the 1st code and "A" digit selectors and, together with Fig. **19**, shows how the varying types of switch base have been accommodated on the standard channel shelf.

Fig. **20** is of particular interest since it shows the director panels split into two sections; the upper carrying the control relays and storage switches, and the lower the B.C. switch and translation field. It will be noticed that the translation field has been set at an angle of 45°, giving full access to the B.C. switch and field terminals.

All the switches in the accompanying photographs have been shipped direct from the factory benches to the exchange in dust proof cases and have received, therefore, the minimum amount of handling, and this gives us the final advantage claimed for piece-meal shipping.

With this article we have now completed the series describing the installation of the first exchange in the London area using throughout the Post Office standard open type racks.

The Author hopes that he has achieved his object of showing the advantages of the "piece-meal" method of handling such a contract, although it is not claimed that such a method would be the most suitable under different conditions.

It must be remembered that in order to reap the full benefit of this system, very close co-operation must be maintained by the Engineering Manufacturing and Installation branches in order to ensure every item falling into its correct position on the schedule.

By the next issue of this Journal, Acorn Exchange should be in service, and it is hoped that we will be able to show a few photographs taken at the actual cut-over, so terminating the complete series.

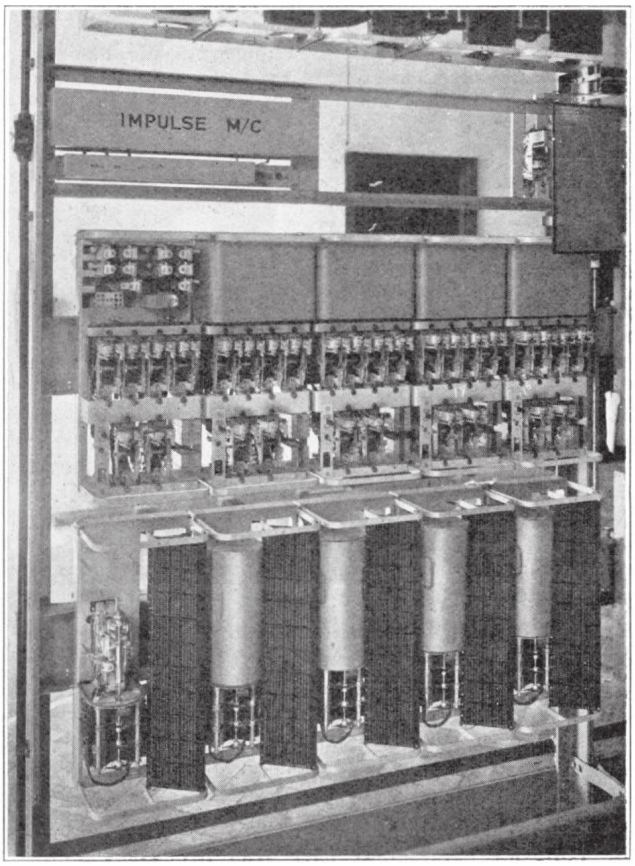


FIG. 20.—DIRECTOR SHELVES.

PRESTON MULTI-EXCHANGE AREA.

A. S. Carr, B.A.

THE recent transfer at Preston has been one of the chief events in the history of the telephone system in the North Western District. Preston, although not the county town, is the practical centre of the County Palatine and the Headquarters of the Lancashire County Council and Police, the P.O. Surveyor, Superintending Engineer and District Manager. Its station houses the largest railway sorting office in the country. There, one sees the ancient fair, the towering cotton mill, the smoky tanker scurrying to the Docks and Leyland chasses in their coats of grey. These features in an agricultural province represent a curious mixture of interests and call for every class of service.

The equipment, which was installed by the General Electric Co., Ltd., is of the standard step-by-step system.

The size of the undertaking can be judged from the following schedule :—

Exchange.	Numbering Scheme.	Present Subs'. lines. Equipment.	Capacity Subs'. lines.
Preston ...	2000-5599 56000159899	3800	7500
Ashton-on-Ribble ...	6100-6899 69000-69699	600	1500
Fulwood ...	7100-7899 79000-79499	700	1300
Leyland ...	81000-82099	600	1100
Penwortham ...	83100-83799	300	700
Ribbleston ...	84100-84899	300	800
Bamber Bridge	85100-85899	Manual	800
Broughton ...	86100-86699	Manual	600
Goosnargh ...	87100-87199	Manual	100
Longton ...	89100-89799	Manual	700

Penwortham and Ribbleton are hypothetical exchanges and are housed temporarily in the H.P.O. which was extended to accommodate the central plant.

New buildings were erected at Ashton-on-Ribble, Leyland and Fulwood. Owing to a variety of causes the Fulwood building was delayed, but although the installation could not be commenced until less than three months before the transfer it was completed according to plan.

At the main exchange the work involved the removal and rearrangement of all the main and local telephone and telegraph cables, and as Preston is a telegraph centre and the largest repeater office in the Kingdom particular care was necessary.

About 6200 subscribers' stations were converted and in connection with the through clearing 1100 stations were condensered.

In order to bring the outcentre exchanges up to the latest standards, modifications were necessary at 31 exchanges.

The Manual Board has a total of twenty-two operating and two unequipped positions.

There are four monitors positions and one supervisor's desk. A three-position Test Desk has also been provided and each satellite exchange has its own Test Desk. It is unnecessary to describe the automatic equipment in detail.

Discriminating selector repeaters at the satellite exchanges are arranged to discriminate on certain digits indicating that the call is for the local exchange. This " drop back " feature enables the switch to fulfil the functions of a second selector on local calls. For other than local calls the switch acts as an auto-to-auto relay set (repeater), holding the connection forward, repeating the impulses from the subscriber's dial over the junction, operating the meter of the calling subscriber when the called party answers and supplying transmitter current to the calling subscriber.

In other cases the preselector hunts and finds an idle discriminating selector repeater, and the secondary line switch then hunts for an idle junction to a first selector at Preston. The first digit dialled is received by both the selector repeater and the first selector, but the wipers of the former are disconnected by the contacts of a relay, thus preventing the call from proceeding in the local exchange. The dialling of the subsequent digits operates the group and final selectors at the other exchanges in the usual manner.

When the call at a satellite is local the discriminating selector repeater drops back after rising to the desired level. The secondary line switch is then disconnected by the operation of a relay, thus releasing the junction to the Preston first selector. The circuit of the wipers of the selector repeater will then be closed by relay contacts, and when the next digit is dialled the wipers will step up again and hunt for a disengaged final selector. The discriminating selector repeaters drop back twice in the case of numbers having five digits.

The inaugural ceremony at Booth's Café was well attended and the stained glass window behind Mr. Shackleton's chair incidentally portrayed his remarks about the former telephone exchange in Glovers Court.

THE PROPOSED POST OFFICE STANDARD TELEPHONE RELAY FOR AUTOMATIC EXCHANGES.

IN the past few years very considerable progress has been made by the Department in its policy of standardising equipment in automatic telephone exchanges. A standard racking scheme and a standard uniselector have been designed and adopted, and concurrently standard circuits have been produced in a large number of cases. It was realised, however, that the full benefit of these developments could not be obtained until standardisation of the relay had been achieved, and to this end Messrs. F. I. Ray and A. W. Biddlecombe, of the Engineer-in-Chief's Office, were instructed to study the relay problem and to produce a relay (either by design, or by selection or modification of an existing type) to be manufactured by all Contractors as the Department's standard for automatic exchanges.

Valuable co-operation and assistance were given by the various sections of the Engineer-in-Chief s Office and by Messrs. A.T.M. Co., Ericssons, G.E.C., Siemens and S.T. & C. Co., and, as a result, a relay was produced incorporating the experience of many years of automatic exchange maintenance and manufacture.

Requirements of a Standard Relay.—Before proceeding with a detailed description of the special features of the proposed P.O. Standard Telephone Relay, brief consideration will be given to the conditions under which relays are used in automatic exchanges and an outline of the chief qualities they must possess. In a director exchange there may be as many as 100,000 relays and during a single call 200 relays and 1500 contact operations may be involved. Many relays have to operate more than 1,000,000 times per annum and a few have to operate as many as 16,000,000 times per annum. The increased size of exchanges and the extended use of common equipment render it more difficult to localise relay faults, and the greater danger of unguarded intervals necessitates a considerable degree of accuracy and uniformity in relay time lags. From these facts it will be understood why, for some time, it has been felt that reliability and uniformity of operation, accessibility and ease of adjustment are qualities of the utmost importance to the Department, since maintenance costs loom large in the balance sheet of an automatic exchange and since a high quality service is needed. A low first cost is of course essential although this must be considered in conjunction with the running costs; for example, battery consumption must be considered, since a cheap but less efficient relay may materially increase the power costs.

The space occupied by the relay should be as small as possible, consistent with maintenance accessibility, but on the other hand facilities must be provided for fitting a reasonable number of springs to avoid the necessity of employing relief relays. In considering the question of space saving it must also be appreciated that in most cases the relays are to be mounted on the same standard base plate as a selector mechanism, *e.g.*, on the group and final selectors. In such cases a saving of even 25% in relay space would only have the effect of decreasing the height of the racks by a few inches and would not permit an extra shelf of selectors to be fitted on the same racks. Consequently it is only on the larger but less frequently used type of apparatus, such as directors and senders, that any substantial space saving would result from the use of a smaller type of relay. Line and cut-off relays present a special case, however, and justify the provision of a smaller type of relay, which is now being developed. The fact that the standard telephone relay must be mounted on a standard selector base has imposed a limitation on its size since two relays must fit side by side within the width of the base plate. This restricts the maximum width of the relay to just over two inches.

Magnetic Circuit.—In considering the proposed P.O. standard relay the first point to be mentioned is its high magnetic efficiency. This is vitally important, because it permits heavy contact pressures to be used and so decreases the risk of contact failure. Magnetic efficiency also permits the use of large residual air gaps and so lessens the possibility of armatures failing to release. Another advantage is that fewer ampere-turns are required to carry a given spring load and, consequently, a winding of higher resistance can be employed with a saving in current consumption.

Magnetic tests made by the Research Section have shown that the magnetic circuit of the Siemen's type knife-edge relay is extremely efficient, and this magnetic circuit has therefore been adopted in the standard relay (Fig. 1). It consists of three pieces, the core over which the coil is wound, the yoke or "heel piece," and the armature. At the front end of the core is welded a round disc of soft iron which provides a pole-face of large cross-section, and so decreases the magnetic reluctance between the core and the armature. The yoke also is provided with an enlarged end which is machined into a knife-edge on which the armature pivots. It will be seen from Fig. 1 that the armature is shaped into a special V bend so that it fits fairly closely over the knife-edge, thus ensuring a low reluctance joint between the armature and the yoke or "heel piece." The only other magnetic joint is that between the yoke and the core, and in order to ensure low reluctance while permitting the core, complete with its winding, to be readily withdrawn without removing the relay from the mounting plate, the method of securing the core to the yoke has been specially designed. The proposed arrangement consists of a

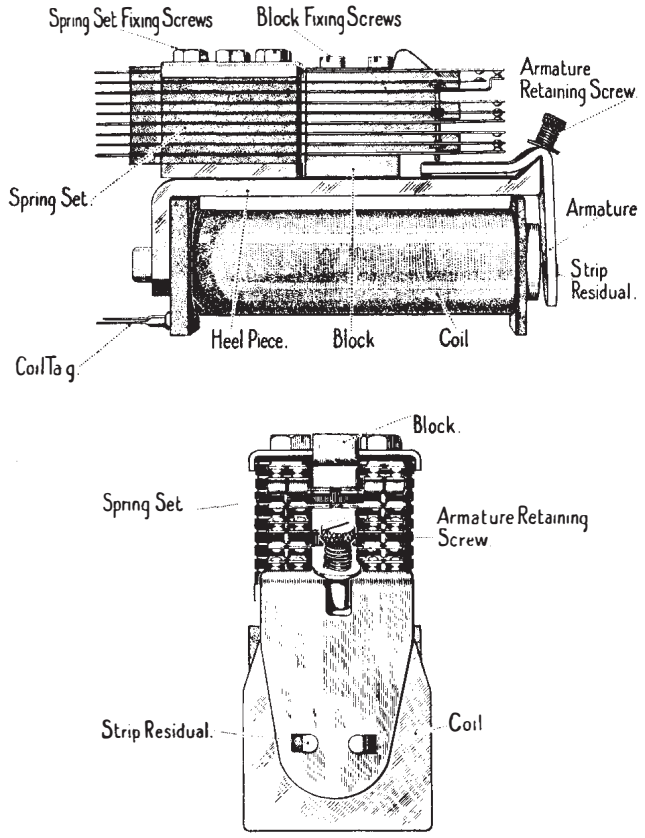


FIG. 1.—THE PROPOSED P.O. STANDARD TELEPHONE RELAY.

flanged nut running on a threaded portion of the core which passes through a clearance hole in the yoke, the yoke itself being recessed to accommodate the flanged portion of the nut. The relay is mounted by means of two screws inserted from the back and threaded into the heel piece quite independently of the core fixing nut.

The Research Section's tests also showed that the anti-corrosion finish of the metal parts greatly effects the magnetic efficiency. Hitherto zinc plating has been extensively employed, but this material, which is non-magnetic, has to be deposited in rather a thick coat and tends to " build up " at the edges. The result is that the zinc protected relays have low impedance at speech frequencies and poor magnetic joints. Nickel, although not as good an anti-corrosion protection as zinc, is highly magnetic, and this metal has therefore been adopted on the proposed standard telephone relay. The use of a very thin deposit or " flash " of cadmium underneath the nickel to improve the protective qualities of the finish, is being considered.

When determining the most desirable form of magnetic circuit the question of magnetic interference between adjacent relays must be considered. To save space, relays must be mounted close to one another and consequently there is a risk that some of the flux produced by the coil of one relay may affect the armatures of adjacent relays. It therefore follows that the performance of a relay may be altered to some extent by the energisation of adjacent relays as regards both sensitivity and speed of operation or release. If the amount of interference be large, great care is necessary on the part of the circuit designers in specifying the position and polarity of all the relays so that the functioning of a circuit is not adversely affected by the operation of groups of relays in all the possible combinations, not forgetting of course the possible interference from relays in other circuits that might be mounted on the same base plate. Further, when a maintenance officer is readjusting a relay, he must make certain that it is not being affected by the flux from other relays, otherwise the readjustment he applies will be incorrect. Cases of magnetic interference have already occurred with a certain existing type of relay, necessitating the removal of the relays affected away from their associated equipment.

It has been suggested that magnetic interference may be advantageous, since a clever designer can make use of it to improve the circuit operation. Thus, a relay could be made more sensitive by placing it near to some other relay that is energised simultaneously, so arranging the polarity of the coils that the leakage flux tends to operate the relay concerned. Such a procedure, however, is dangerous as the correct functioning of the circuit would be jeopardised if a maintenance officer, in replacing a disconnected coil, were to transpose the connections and so alter the polarity, or if the conditions for correct interference were to be altered by modifications to the equipment. It is therefore safer as well as simpler to use a type of relay in which magnetic interference is as small as possible.

The more efficient the magnetic circuit, the smaller the amount of leakage flux and consequently the smaller is the amount of magnetic interference; another factor is the proximity of the armature of one relay to the coils of others. Tests have shown that the amount of flux leakage with the Siemens' knife-edge magnetic circuit is particularly small and this is an additional reason for its adoption in the standard relay.

As has been mentioned previously, the increased magnetic efficiency permits the use of a large residual air gap between the armature and the core when the relay is energised. In certain cases this gap must be adjustable to permit the releasing lag to be controlled, and in such cases a small screw is placed in the armature, the tip projecting into the air gap a sufficient distance to provide the required clearance when the armature is operated. This arrangement suffers from the disability that the area of contact between the tip of the screw and the core is very small, and consequently wear takes place causing the residual air gap to be gradually decreased. The effect of this wear has been minimised in the proposed standard relay by fixing a minimum gap of 4 mils, and also by the design of the relay which ensures that the residual screw strikes the core

perpendicularly. Whenever an adjustable residual screw is not essential, it is better to employ a strip of non-magnetic metal foil instead of a screw, as by this means the area of contact can be increased. In the standard relay two holes have been made in the armature (Fig. **1**) to provide a fixing for this strip, for which thicknesses of 4, 12 and 20 mils have been proposed. To facilitate identification it has been arranged that the 4 and 20 mil strips should be of phosphor bronze and the 12 mils strip should be of nickel silver.

The relay is normally mounted with the springs at the side as shown in Fig. **2**, since experience has

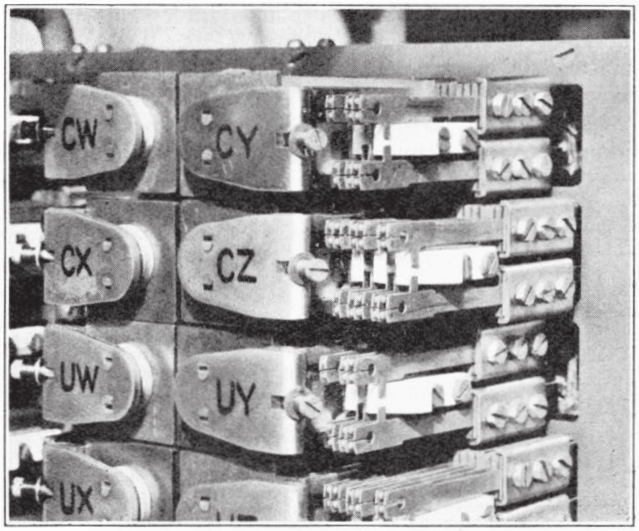


Fig. 2.—P.O. Relays mounted. Early examples at Shepherds Bush Exchange.

shown that in that position the fault liability of the contacts is a minimum. Means must, however, be provided to prevent the armature falling away from the knife-edge. This is effected by an armature retaining screw fitted with a spring loaded washer. (Figs. **1** and **3**). When in position the spring is compressed and therefore thrusts the armature against the knife-edge. The lower part of this screw is of slightly larger diameter than the hole in the washer, so that the washer and spring will not fall off when the screw is removed. It will be appreciated that the function of this armature retaining screw is merely to hold the armature against the knife-edge when the relay is demagnetised, since the combined forces of the spring pressure and the magnetic pull will assuredly hold the armature in position as soon as magnetisation commences.

Spring Assembly.—The space available for the springs is limited by the necessity of mounting two relays side by side on a standard mounting plate; also, the distance between successive springs and between adjacent piles of springs must be sufficient for visual inspection, and for the insertion of adjustment tools. In view of these requirements it was decided to restrict the number of spring piles per relay to two, and to permit no more than nine springs to be assembled in any pile. The distance between adjacent springs is 55 to 60 mils and a very simple spring bender has been designed to facilitate adjustment, the corners of the front cheek being cut off in the latest design, as in Fig. **1**, to give ample room for the manipulation of such adjusting tools.

Each pile of contact springs is formed into a unit, being held together by the central of the three screws provided, the others serving to secure the pile rigidly to the yoke (Fig. **3**). The clamping plates and insulators have been made of ample dimensions to give a rigid assembly, while the insulators are arranged to project through the mounting plate to decrease the danger of contact faults being caused by spring tags touching or being bridged by pieces of solder, etc. The insulators are of the half-sheared type, which render the spring

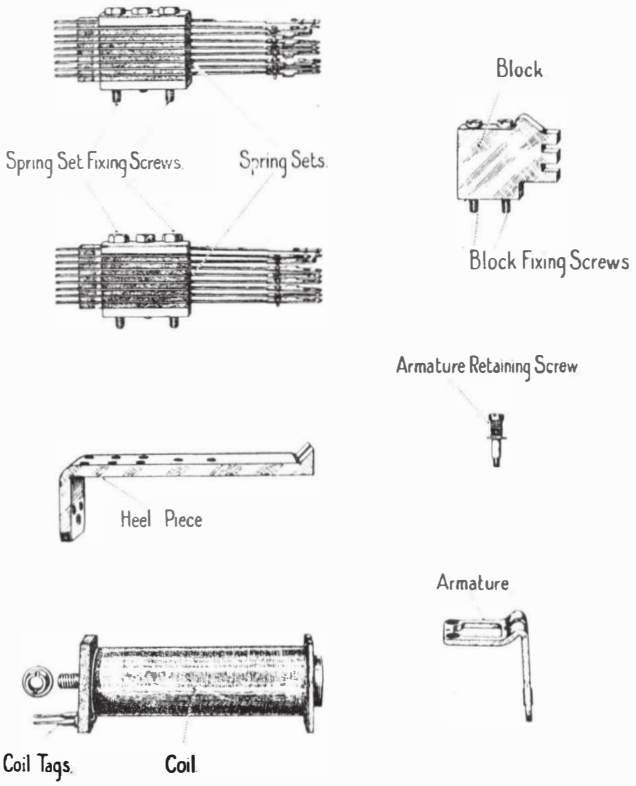


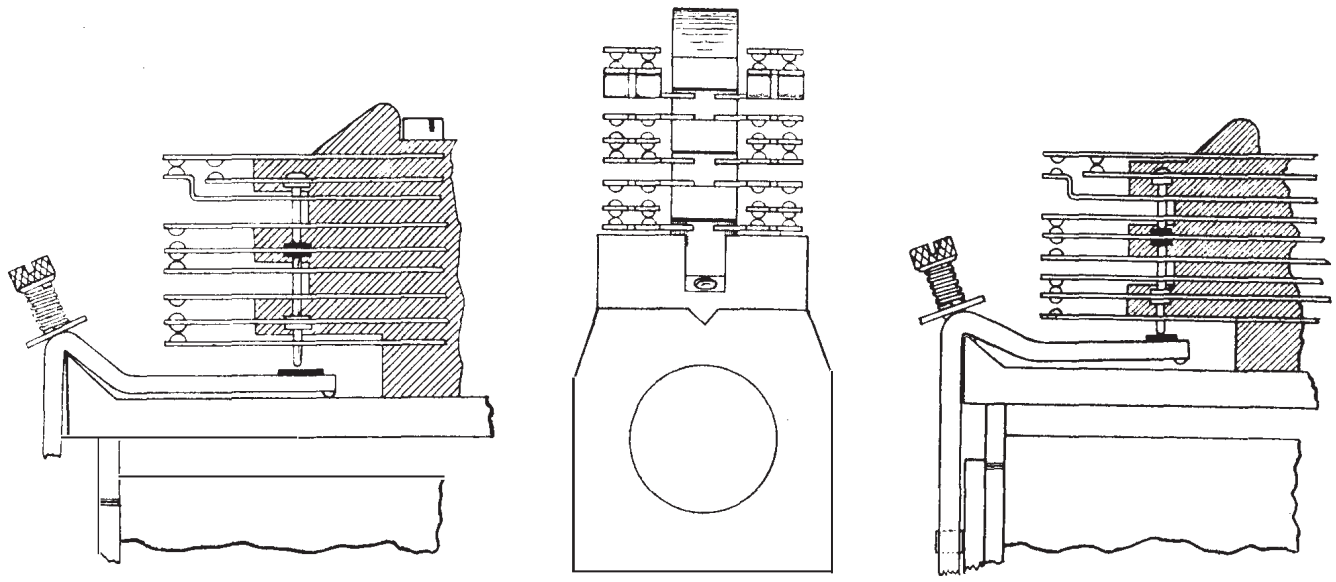
Fig. 3.—Assembly details of P.O. Relay.

pile self-locking, and so make assembly easier than with some earlier type springs which were threaded over ebonite tubes through which the fixing screws were passed. Except for heavy duty contacts which will be of platinum, twin silver contacts are proposed, since tests have shown that their fault liability is only a small fraction of that of single or double contacts of any other material.

The actual shape of the contact springs adopted is closely bound up with the method of adjustment to be employed. Except in the case of relays which have to meet some marginal circuit requirement

(and with sound circuit design such cases should not occur frequently) the sole object of adjusting a relay is to ensure that when the contacts are closed the pressure between them is adequate, and that when they are separated the distance between them is sufficient. Hitherto, the most common method of adjustment has been by specifying that individual contacts shall touch when a feeler gauge of a given thickness is inserted in the armature air gap and the armature is attracted. For example, it might be specified that with a 4 mil gauge a pair of " make " contacts should just touch; then, if the ratio of movement of the contacts to the movement of the armature is 3 : 1, the contacts will move through a distance of $3 \times 4 = 12$ mils when the relay operates fully. This displacement will result in a certain pressure between the contacts, the value of which depends upon the thickness, shape and material of the contact springs. This process, known as " gauging," is not sufficient by itself, since it does not control in any way the tension of the moving springs or of the break contacts, and consequently it is also necessary to specify operate, and non-operate, currents for the relay—not because the relay has to meet marginal circuit conditions, but as part of the adjustment of the springs. Even so, this method of adjustment fixes only its *total* break contact pressure, and the pressures at individual break contacts are not controlled. " Gauging " is a process which requires considerable care and experience, even when applied to single contact relays on an adjustment bench, and it is still more difficult when twin contacts are used and when the relay is mounted on a rack. Adjustment to an operate current necessitates the insertion of an adjustable resistance in series with the coil of the relay, a process which, in view of its practical maintenance difficulties, may well be avoided except for meeting special marginal conditions of operation.

It was therefore considered preferable to adopt a scheme in which the contact pressures were obtained by direct measurement and in which adequate contact opening was obtained by the design of the relay rather than by the adjustment of the contact springs. The spring set which has been specially designed for the purpose has very considerably simplified the adjustments, representing an advantage to the manufacturer who can thereby decrease the time required for adjustment in the factory, and to the maintenance officer who has to readjust a faulty relay. On the P.O. relay, a buffer block (Fig. **3**), made of white insulating material, is placed between the two spring sets. The so-called " fixed " springs, both " make " and " break," are provided with projections which rest upon shoulders in this block and the springs are tensioned so that a pressure of, say, 30 grammes applied by a pressure gauge at the contact will just lift the projection away from the block. It follows that if, when the relay operates, the projection is just lifted away from the block, then the contact pressure must be at least 30 grammes. A study of Fig. **4** will show that on each change-over spring set, the " break " spring rests on one side of a shoulder and the " make " spring rests on the other. The moving spring lifts the " break " spring off the block when the relay is normal, but changes over and lifts the " make " spring off the block when the relay is energised. The contact opening will depend chiefly upon the distance between the break and make springs and as



(*a*) Armature unoperated. (*b*) Front view. Armature removed. (*c*) Armature operated.

FIG. **4.**

this distance is fixed by the width of the shoulder of the buffer block, adequate contact clearance is obtained by relay design and is not dependent upon adjustment. The process of adjusting a relay is therefore (i) to tension all make and break springs against the block, (ii) to tension the moving springs so that they will lift the break springs away from the block when the relay is de-energised, (iii) to check that the armature travel is correct, and (iv) to check that the make springs are lifted away from the block when the relay is operated. Adjustments to operate and non-operate currents are required only in cases where special circuit requirements render them necessary, *i.e.,* when a relay must operate under one circuit condition and not under another. With this type of spring assembly the adjustment can be checked roughly by inspection, *i.e.,* by seeing that the fixed springs lift correctly, and can be checked accurately by testing the tension in the fixed springs by a tension gauge, a very simple method, especially as all springs on one relay will have the same tension. The buffer block, being white, forms an excellent background when making such inspections.

For small spring assemblies a block with two shoulders is proposed, giving a capacity of four moving springs (see relays CY and UY in Fig. **2**). In larger assemblies a block with three shoulders is used, permitting six moving springs to be employed. With the relay in its present form it is not possible to use more than six moving springs and this involves a slight limitation upon the circuit designer. It was felt, however, that to exceed this number would be to prejudice the ease of adjustment and therefore to increase the fault liability under service conditions.

Relays which have an adequate operate current and which do not have to be slow to release are fitted with 18 mils nickel-silver springs and adjusted to a standard spring pressure of 30 grammes, measured as described above. For other relays a pressure of 18 grammes and a thickness of 14 mils has been standardised. It is realised that in exceptional cases the circuit conditions would necessitate thinner springs and lower contact pressures and that 12 mil springs with 10 grammes contact pressure might be unavoidable. These should, however, be considered as non-standard. At present it is customary to judge a circuit by the number of relays or contacts that it involves. By adding the third criterion, that the number of non-standard relays should be as few as possible, it is considered that a more accurate method of estimating the relative merits of different circuits would be available and that the number of such special relays would therefore gradually be decreased. The use of springs of different thicknesses on the same relay is avoided, thus reducing the number of types of assembly to be manufactured or to be stocked by the department for replacement purposes.

Contact Bounce.—In the design of the proposed P.O. Standard Relay, special attention has been paid to contact bounce. When the circuit of a relay is disconnected and the flux begins to decay more or less rapidly according to the presence or absence of slugs, short-circuited windings, etc., a stage is reached when the pull of the armature is less than the restoring force of the springs and the armature begins to return to normal. As soon as the make contacts open, however, a large part of the restoring force is removed and, unless the flux decay has been extremely rapid, the pull on the armature will momentarily exceed the restoring force. The movement of the armature is therefore checked, but the armature does not stop instantly, owing to its inertia, and so an oscillation is set up causing the contacts to be opened and closed momentarily. This results in what is usually called "contact bounce." The effect is particularly noticeable on a slow releasing relay, owing to the slow collapse of the flux. It has been found possible to prevent this oscillation of the armature by placing a copper plate near it and this plate has been incorporated in the standard relay, being threaded over the core and adjacent to the pole face, where it also acts as a front cheek for the relay coil. The movement of the armature and the current in the contacts of a relay with and without this copper plate are shown in oscillograms in Fig. **5**. This plate is intended for use on all except high impedance relays.

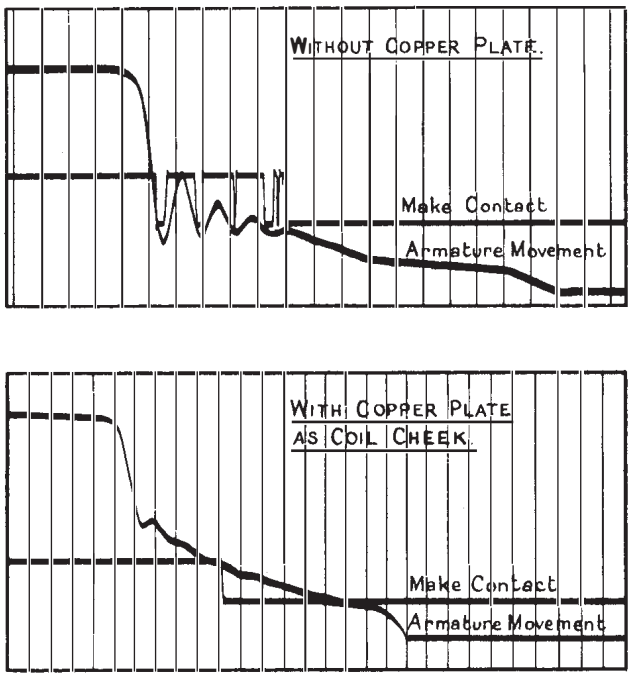


FIG. 5.—CONTACT OPERATION ON SLOW RELEASE RELAY.

Service trials.—At various stages in the development of the proposed Post Office Standard Telephone Relay a number of samples were produced and were subjected to laboratory tests, but since the final proposals did not involve any radical departures from

existing relay practice, it was thought that no good purpose would be served by subjecting a large number of samples to an extensive durability test in the laboratory. It was decided therefore to proceed at once with service trials, and for this purpose five large London Exchanges were equipped with a 4-digit keysender with relays of the proposed standard type. The Exchanges selected were Flaxman, Ilford, Shepherds Bush, Fulham and Primrose, G.E.C., Siemens, Ericssons, S.T. & C., and A.T.M. Co. respectively, and an order was placed with each contractor to manufacture and supply one model shop sample keysender with relays of the new type (Fig. 6). These five samples were then brought into service side by side with the old equipment, special records being taken of all faults that developed in them. The senders at Flaxman and Ilford Exchanges have now been in service for 12 months, having completed 300,000 operations between them, and the others, installed later, have added a further 100,000 operations to date, making a total of 400,000 operations in all.

During this time no relay faults whatever have occurred, nor has it been necessary to interfere with the new relays in any way. This result is striking when it is considered that the average relay fault liability at the five Exchanges for such a number of operations is 18 per sender with existing types of relays. In some respects it is unfortunate that a trial which was intended to reveal the fault liability of the new relays should have given a negative result, since it is obvious that no commercial telephone relay could be entirely immune from faults of one kind or another during its life, but undoubtedly the results obtained during a 12 months service trial of two complete sets of relays working under some of the most onerous conditions in an automatic exchange are of more value than any prolonged laboratory life test which cannot simulate the actual service conditions.

In view of the satisfactory results obtained, orders have now been placed for 100 Rural Automatic Exchanges to be equipped with the proposed Post Office Standard Telephone Relay, and there is no doubt that this step will be fully justified by reduced maintenance costs and higher service efficiency.

R.W.P.

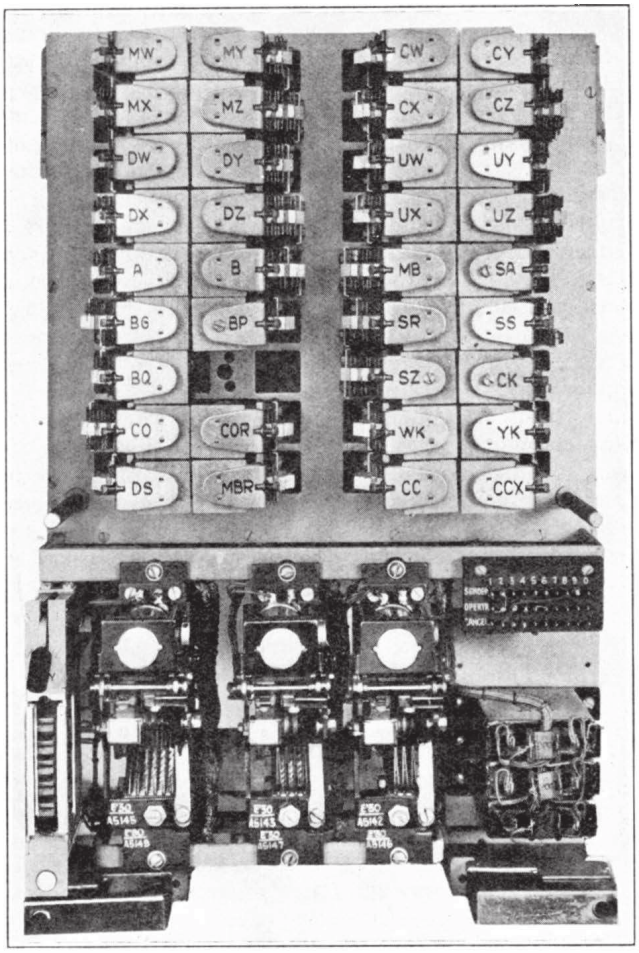


FIG. 6.—KEYSENDER AT SHEPHERDS BUSH EXCHANGE. (EARLY SAMPLES).

AN OSCILLOGRAPHIC METHOD OF RECORDING MAGNETIC FLUX.

AND SOME RECORDS OF THE FLUX IN TELEPHONE RELAYS.

L. H. HARRIS, M.Sc., A.C.G.I., M.I.E.E.

THIS article describes an oscillographic method of obtaining records of varying flux. Typical examples of such records are included, showing the flux in telephone relays under various conditions.

In Research Work on electromagnetic relays and similar apparatus the oscillograph affords an excellent means of examining current transients during switching processes. It has been universally used for investigations of impulsing and automatic telephone relay operation generally, including the examination of armature and spring bounce, and in connection with the latter it has been modified to enable the actual movement of the armature and springs to be recorded simultaneously with the coil and contact currents. In general, records of current

are neither a measure nor a direct indication of the flux-time characteristics, since the latter are dependent not only on the currents in the windings but on all the current paths (*e.g.*, the core itself) linked with it. Measurements of flux have had to be confined to static conditions and while theory, indirect confirmation of theory and familiarity with the subject give considerable insight into the behaviour of the flux, the need for a ready means of obtaining direct confirmation by an oscillographic method has become increasingly apparent.

Providing a suitable amplifier capable of dealing with very low frequencies (*e.g.*, D.C. impulses at 10 per second) and having a final stage suitable for the operation of the electromagnetic oscillograph is available, the problem of using the latter to record flux reduces to a simple application of well known principles.

Method.—The E.M.F. induced in a search coil linked with a varying flux is proportional to the time rate of change of flux. The flux at any instant is therefore proportional to the time integral of the search coil voltage.

If the search coil voltage is employed to charge a condenser sufficiently large through a resistance sufficiently high to render the condenser voltage negligible compared with the search coil voltage, then the charge current to the condenser will be proportional to the search coil voltage and the condenser charge (and therefore voltage) will be proportional to the time integral of the search coil voltage. The P.D. of the condenser will therefore be proportional to the flux. Amplification of this condenser P.D. to suit the oscillograph then enables records of flux to be made simultaneously with currents or voltages.

An alternative to this large condenser and resistance method of integrating a variable voltage is the similar one of using a large inductance of low resistance, in which case the current flowing is approximately proportional to the time integral of the voltage. These methods have been described at various times in connection with schemes which have been developed for recording hysteresis loops and for which reference can be made to E. L. Bowles, J.A.I.E.E., p. 849, 1923, Charlton and Jackson, J.A.I.E.E., p. 1,220, 1925, and J. B. Johnson, Bell System Journal, p. 286, VIII., 1929.

Theory of Integrating Circuit.—The instantaneous E.M.F. induced in a search coil by a varying flux ϕ is given by

$$v = -N\frac{d\phi}{dt}$$ where N is the number of turns on the search coil.

Applying this E.M.F. to a circuit consisting of a high resistance R and a large capacity C in series gives :

$$\frac{q}{c} + Ri = -N\frac{d\phi}{dt}$$

where q and i are the instantaneous values of the condenser charge and current respectively. Since $i = \frac{dq}{dt}$ this can be rewritten

$$\frac{dq}{dt} + \frac{1}{CR}q = -\frac{N}{R}\frac{d\phi}{dt}$$

The solution of this differential equation is

$$qe^{\frac{t}{CR}} = A - \int \frac{N}{R}\frac{d\phi}{dt}\, e^{\frac{t}{CR}}\, dt$$

where A is a constant depending on the initial condition of the circuit.

In any practical case ϕ can be expressed as a Fourier series thus :

$$\phi = \Phi_0 + \sum_{n=1}^{n=\infty}(\Phi_n \sin n\omega t + \Phi_n \cos n\omega t)$$

where n is made successively equal to all the positive integers and Φ_0 is the arithmetic mean value of the flux.

Differentiating the flux gives :

$$\frac{d\phi}{dt} = \sum_{n=1}^{n=\infty} -\Phi_n n\omega \sin n\omega t + \Phi_n n\omega \cos n\omega t$$

and the solution of the above differential equation now becomes :

$$qe^{\frac{t}{CR}} = A - \frac{N}{R}\int e^{\frac{t}{CR}} \sum_{n=1}^{n=\infty} n\omega\,\Phi_n(\cos n\omega t - \sin n\omega t)\cdot dt.$$

Now $\int e^{\frac{t}{CR}} \sin n\omega t \cdot dt = e^{\frac{t}{CR}} \frac{CR}{1 + \omega^2 n^2 C^2 R^2}$

$$(\sin n\omega t - \omega n CR \cos n\omega t)$$

and $\int e^{\frac{t}{CR}} \cos n\omega t \cdot dt = e^{\frac{t}{CR}} \frac{CR}{1 + \omega^2 n^2 C^2 R^2}$

$$(\cos n\omega t + \omega n CR \sin n\omega t)$$

Substituting these values and dividing throughout by $e^{\frac{t}{CR}}$ gives :

$$q = Ae^{-\frac{t}{CR}} - \sum_{n=1}^{n=\infty} \frac{N}{R}\frac{CR\omega n}{1 + \omega^2 n^2 C^2 R^2}$$

$$\Phi_n[(-1 + \omega n CR)\sin n\omega t + (1 + \omega n CR)\cos n\omega t]$$

Supposing $\omega n CR$ is large compared with unity this becomes

$$q = Ae^{-\frac{t}{CR}} - \frac{N}{R}\sum_{n=1}^{n=\infty}\Phi_n(\sin n\omega t + \cos n\omega t)$$

As the second term is proportional to the variable part of the flux it will be seen that the accuracy with which the condenser voltage follows the flux variation depends on the values of the capacity and resistance used and on the fundamental frequency of the flux variation. With 20 μF and 100,000Ω

at 10 p.p.s. $\omega CR = 125$, showing that the departure from true integration of the search coil voltage at impulsing speeds is small as regards the fundamental of the flux and smaller still as regards the harmonics.

The term $Ae^{-\frac{t}{CR}}$ represents the transient condition due to the condenser being initially discharged when the flux has a definite value $\Phi_0 + \sum_{n=1}^{n=\infty} \Phi_n$ at $t = 0$. Where tests of a continuously repeated nature are being made, this term has no effect after the first few seconds, since it has by then become zero, but it is important when it is desired to test a condition which is not continuous and which persists for sufficient time for $e^{-\frac{t}{CR}}$ to depart appreciably from unity. When the test consists of a single operation occupying a small time compared with the value of CR seconds, the error introduced by this term may be neglected.

Amplifier.—Neglecting the flux harmonics the condenser P.D. is of the order of $\frac{N\Phi_1}{RC} \times 10^{-8}$ volts which with a search coil of 50 turns, $\Phi_1 = 2000$, R = 100,000 ohms and C = 20 μF, gives 0.5 millivolts. This P.D. is applied directly to the grid of the first stage of an amplifier, the anode circuit of the fourth stage of which is connected directly in series with the oscillograph vibrator. The latter has a sensitivity of the order of 40 mA per cm. and the last stage was therefore made capable of dealing with overall variations of the order of 80 mA (2 cms.) by using four L.S.5 valves in parallel and a battery voltage of 300. The first three stages consist of valves H.L.610 (amplification factor = 40) with capacity resistance couplings comprising 160,000Ω anode resistances, 5 μF coupling condensers (of high insulation resistance) and 2 MΩ leaks. The amplification per stage given by these valves when used with a 150 volt battery and 160,000 ohms anode resistance is of the order of 25. The large time constant of the couplings (10 secs.) enabled the amplifier to be used down to 10 cycles per second without appreciable distortion. Owing to the large filament current taken by the power stage (4 × .8 amps) and the effect of the large emission on the filament brightness it was found beneficial to use a separate filament battery (6 v.) for the first stage. The use of decoupling resistances and condensers in the anode supply to each stage was found to affect the characteristics adversely and a separate 150 volt battery was therefore used to supply the first stages instead of tapping the 300 volt power stage battery.

Grid bias was provided on the first stage by direct connection *via* the integrating resistance and search coil to the earthed negative of the filament battery and on the second and third stages by utilizing the voltage drops in resistances used to supply the 6 volt valves from an 8 volt battery. A grid bias battery variable up to −36 volts was provided for the power stage.

The first three valves were packed in cotton wool inside cardboard and lead cylinders for acoustic and electrostatic screening and the whole assembled in a subdivided screened box, the batteries also being screened separately.

Performance of Amplifier and Oscillograph.—Fig. 1, Sheet I., shows the overall performance of the amplifier and oscillograph. The input consisted

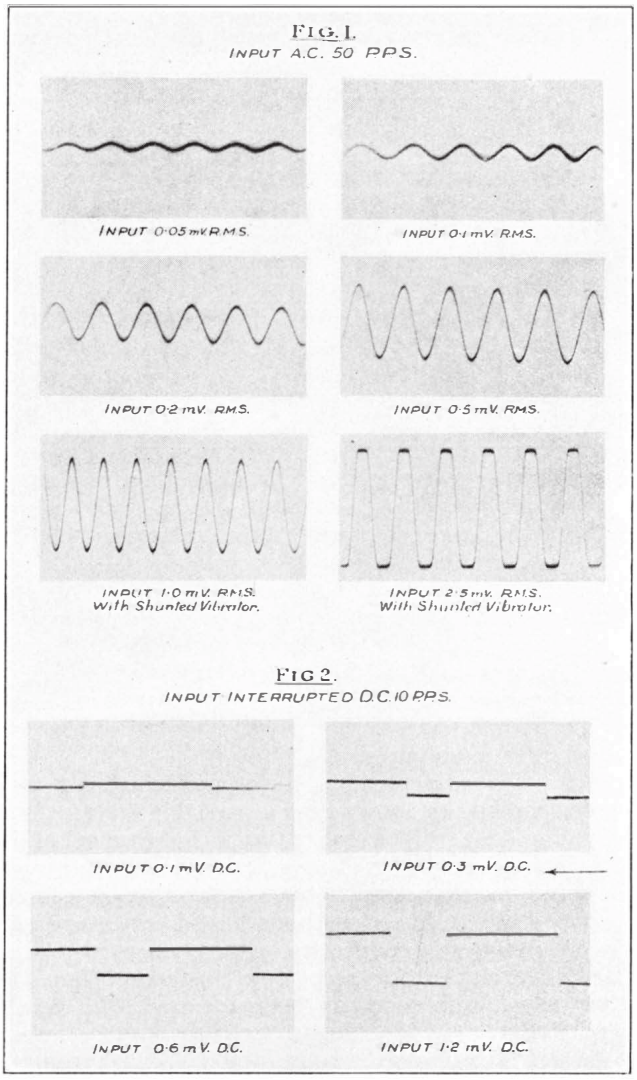


FIG. 1.
INPUT A.C. 50 P.P.S.
INPUT 0·05 mV. R.M.S.
INPUT 0·1 mV. R.M.S.
INPUT 0·2 mV. R.M.S.
INPUT 0·5 mV. R.M.S.
INPUT 1·0 mV. R.M.S. With Shunted Vibrator.
INPUT 2·5 mV. R.M.S. With Shunted Vibrator.
FIG 2.
INPUT INTERRUPTED D.C. 10 P.P.S.
INPUT 0·1 mV. D.C.
INPUT 0·3 mV. D.C.
INPUT 0·6 mV. D.C.
INPUT 1·2 mV. D.C.

SHEET I.—PERFORMANCE OF AMPLIFIER AND OSCILLATOR.

of A.C. of 50 p.p.s. having values of 50, 100, 200, 500, 1000 and 2500 R.M.S. micro-volts; with the last two voltages the vibrator was shunted by 20Ω. The oscillograms show that saturation of the last stage occurs with an R.M.S. input of about 1¾ millivolts, but the wave tends to become unsymmetrical before this value is reached. By limiting the overall width of records to approximately 2 cms., distortion due to overloading may be neglected.

As the magnetic properties of relays at ringing or impulsing frequencies was of particular interest, the

frequency characteristic of the amplifier was tested by means of 10 p.p.s. square topped input voltage. Fig. **2**, Sheet I., shows the results obtained when the overall voltage change on the input grid was 0.1, 0.3, 0.6 and 1.2 millivolts.

The evidence of Figs. **1** and **2**, together with similar oscillograms and measurements, indicated that the amplifier could be relied upon to give a record of the integrating condenser P.D. with satisfactory accuracy.

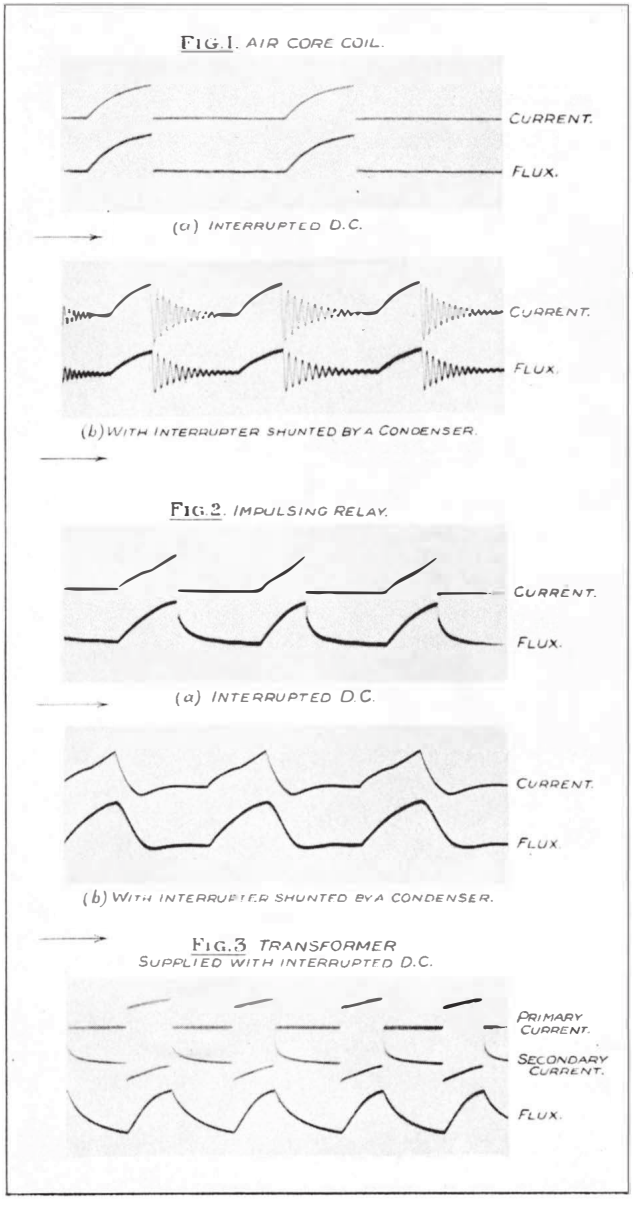
Check of Method.—Comparison of simultaneous records of the current and the flux of air cored coils in which, in the absence of eddy current paths and secondary circuits, the flux and current waves are identical, gives an experimental means of checking the overall performance of the method.

Fig. **1** (*a*), Sheet II., shows the current and flux for an air cored coil when supplied with interrupted D.C. at 10 I.P.S. Fig. **1** (*b*), Sheet II., is similar but includes the oscillation that occurs at break when the interrupter contacts are shunted by a condenser. The records indicate that the apparatus is capable of reproducing repeated flux waves embodying frequencies as low as 10 periods per second and at least as high as the oscillograph vibrator (3000 periods per sec.) warrants. Records of single impulses lasting 200 milliseconds served as a further check for the reproduction of a flux wave lasting a small time compared with the time constants of the integrating circuit and amplifier couplings.

Examples of Flux Records using Iron-Cored Coils.—Oscillograph records of current and flux for various conditions occurring frequently in telephone practice have been obtained with the object of examining the possibilities and limitations of the method and at the same time obtaining information as to the mode of flux variations not previously possible by direct means.

The Impulsing Relay of the Strowger Impulsing Circuit.—Fig. **2**, Sheet II., shows the current and the flux in the case of this relay under impulsing conditions. Fig. **2** (*a*), Sheet II., refers to the condition existing when the interrupter contacts are connected directly in series with the battery and the relay winding, while Fig. **2** (*b*), Sheet II., refers to the more usual condition in which a 2 μF condenser is connected across the interrupter contacts. In the first case the flux is dependent solely on the M.M.F. of the circulating currents in the iron since the winding current drops instantaneously to zero. The flux curve at " break " therefore shows an initial sudden drop (due to the disappearance of the leakage flux) followed by a slower decay dependent on the circulating currents. In the second case the flux is dependent on the sum of the M.M.F's of the condenser current and circulating currents. The effects of saturation and the core currents are well shown by the difference between the current and flux curves.

Interrupted D.C. applied to a Transformer.—This provides an example of current records which are no direct indication of the flux, owing to the latter being dependent on the sum of the M.M.F's of the two windings. If the coupling between the windings is complete, the primary current rises instantaneously at " make " to $\frac{T_2}{T_1 + T_2}$ of its final value where T_1 and T_2 are the primary and secondary



SHEET II.—THE CURRENT AND FLUX IN VARIOUS INDUCTIVE CIRCUITS WHEN SUPPLIED WITH INTERRUPTED D.C.

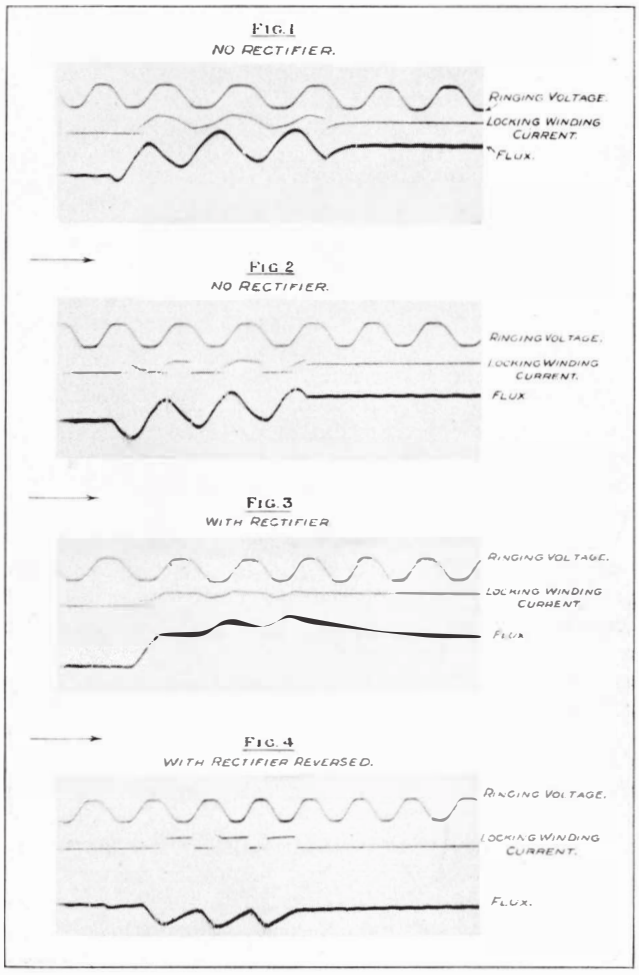
time constants, and then, assuming constant permeability, grows logarithmically (time constant $T_1 + T_2$) to its full value $\frac{E}{R_1}$, and finally drops instantaneously to zero at " break." The secondary current also rises instantaneously at " make " to a

value $\frac{E}{R_2}\frac{T_2}{(T_1 + T_2)} \times \frac{n_1}{n_2}$ where n_1 and n_2 are the primary and secondary turns. It then dies away logarithmically (time constant $T_1 + T_2$) until "break" when it rises instantaneously to $\frac{E}{R_1}\frac{n_1}{n_2}$ on the transfer to the secondary of the primary M.M.F. Finally, the secondary current dies away logarithmically, the time constant being T_2. Unlike the currents, the flux cannot rise instantaneously and therefore obeys a law at "make" of simple logarithmic growth from zero to its maximum value, the time constant being $T_1 + T_2$, while at "break" the time constant of the decay is T_2. Fig. **3**, Sheet II., illustrates the primary and secondary currents and the flux on connecting interrupted D.C. to the primary of a repeating coil having a short-circuited secondary. In this particular record the "make" period was not quite sufficient for the primary current and flux to rise to their full values.

The Operation and Locking of a Relay Shunted by a Rectifier when supplied with Ringing Current.—In connection with another investigation which referred to the use of ordinary D.C. relays shunted by a rectifier as A.C. relays, the opportunity was taken of examining the flux and current on operation under various conditions. Each of the oscillograms on Sheet III. shows the applied voltage, the locking winding current and the flux when about 3 cycles of A.C. at 16 periods per second (flat topped) are applied to the operating winding of a relay having a second winding supplied with D.C. *via* its own "make" contact. The irregularities in the flux curves are due to the direct pick up by the amplifier of the inductive voltages due to the chattering contacts carrying the locking winding current. Figs. **1** and **2**, Sheet III., are two examples taken without a rectifier. Fig. **1**, Sheet III., shows the operation when at the instant of switching on the A.C., the point in the cycle is favourable to quick locking. Fig. **2**, Sheet III., shows the operation where the relay first operates with the A.C. M.M.F. in a direction opposed to that of the locking winding and also shows the irregularities consequent on the chattering of the contacts due to the opposing M.M.F's. The use of a rectifier shunt on the operating winding of the relay (connected with correct polarity) ensures that the operating M.M.F. is of the same sign as that of the locking winding and therefore avoids the trouble shown in Fig. **2**. The flux growth with a rectifier is shown in Fig. **3**, Sheet III., where the satisfactory quick operation of the locking winding is apparent. Fig. **4**, Sheet III., is a record obtained with the rectifier wrongly connected and it will be seen that the relay failed to lock during the 3 cycles for which the A.C. was applied. After the locking winding has been closed by the contact, this winding acts as a secondary winding short-circuited through a battery and it has therefore ringing current superimposed on the D.C. until the operating winding is disconnected. This is well shown in Figs. **1** and **3** of Sheet III.

The C Relay of the Strowger Impulsing Circuit.—This relay is of low resistance (4Ω) and works in series with the switch magnet (46Ω). It receives therefore from 1 to 10 impulses of one ampere and is designed to come in on the first and hold in until after the last impulse.

The current in the circuit is determined almost entirely by the magnet since this preponderates both in resistance and inductance. The C relay is fitted with a small slug or a sleeve to enable it to hold over the no current periods of about 38 milliseconds



SHEET III.—OPERATION ON 3 CYCLES OF RINGING CURRENT OF A RELAY WITH A D.C. LOCKING WINDING. EFFECT OF A RECTIFIER SHUNT.

duration. Fig. **1** (*a*), Sheet IV., shows the current and flux in a slugged relay during a train of 4 impulses. It will be seen that the relay flux on "make" rises with the circuit current and reaches its maximum soon after the current. The relay flux on make is therefore chiefly dependent on the time constant of the vertical magnet and not on the time constant of the slug as is the case if the latter is completely coupled with the winding. On "break" the current drops to zero, accompanied by the quench

oscillation, while the leakage flux of the relay similarly decays in phase with this oscillation. The flux coupled to the slug subsequently dies away at a slow rate, depending on the time constant of the slug, but not to a value sufficiently small for the relay to release. On the next " make " the flux again rises from the minimum value reached to the same maximum as before.

In the case of the sleeved C relay, Fig. **1** (*b*), Sheet IV., the coupling is almost complete and, although the winding current is still largely determined by the switch magnet, the relay flux now lags considerably behind the current. At each " break " of the

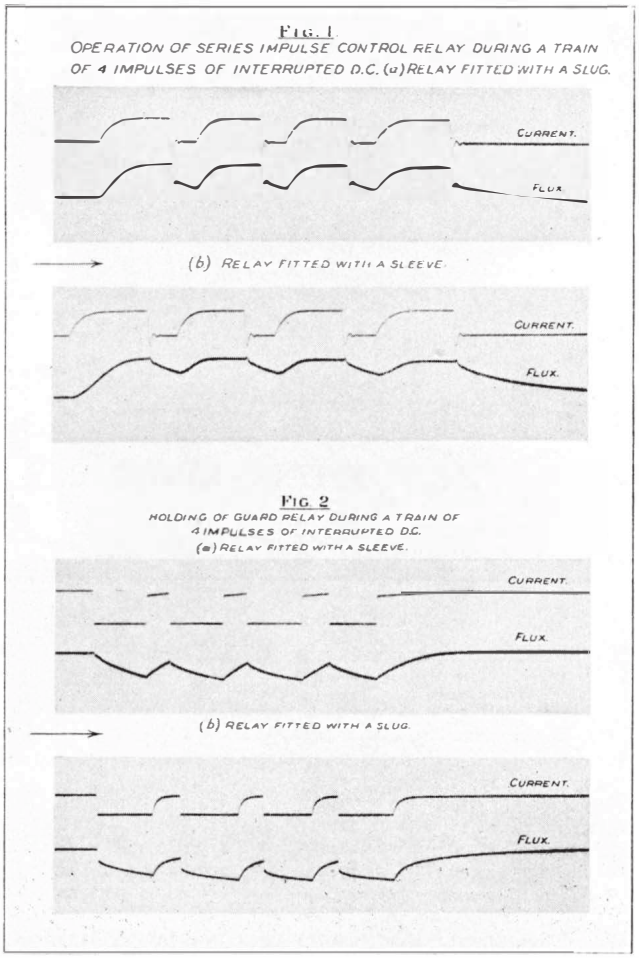


FIG. 1
OPERATION OF SERIES IMPULSE CONTROL RELAY DURING A TRAIN OF 4 IMPULSES OF INTERRUPTED D.C. (a) RELAY FITTED WITH A SLUG.
CURRENT.
FLUX.
(b) RELAY FITTED WITH A SLEEVE.
CURRENT.
FLUX.
FIG. 2
HOLDING OF GUARD RELAY DURING A TRAIN OF 4 IMPULSES OF INTERRUPTED D.C.
(a) RELAY FITTED WITH A SLEEVE.
CURRENT.
FLUX.
(b) RELAY FITTED WITH A SLUG.
CURRENT.
FLUX.

SHEET IV.—OPERATION OF GUARD AND SERIES IMPULSE CONTROL RELAYS OF STROWGER IMPULSING CIRCUIT.

current the M.M.F. of the winding is transferred almost completely to the sleeve, the leakage flux is negligible and instead of a sudden drop occurring in the flux curve, as in the case of the relay fitted with a slug, the flux now decays logarithmically until the next " make."

The above disproves the generally held idea that the flux curve in the C relay is of the form of a rising saw tooth. It appears that in predicting this shape the most important effects of the 46Ω switch magnet itself and the leakage in the series (slugged) relay have been neglected, while the effect of saturation of the iron cannot be neglected in this case without further deviation between theory and practice.

Saturation complicates the process of flux and current growth and decay to a very marked extent. If the time constant of the winding predominates, as compared with those of the other coupled circuits, the growth of flux on closing the winding circuit is relatively quicker than the growth of current, while on the decay due to the equivalent condition of short-circuiting the winding the flux decays relatively more slowly than the current. If secondary circuits are present, the same applies to the relative rates of growth of the M.M.F. and the flux, but the winding current is now no indication of the rate of growth of the M.M.F. Under the same condition of energisation as of de-energisation (*e.g.*, removal or application of a short-circuit to the winding which, in the case of constant permeability, would give precisely the same growth and decay curves) the flux growth is more rapid than the flux decay, showing that the equivalent time constants of the various current paths are different for the two cases, while in the case of a relay further variation is of course introduced due to the reluctance altering on operation.

The " B " Relay of the Strowger Impulsing Circuit.—In this case a high resistance relay fitted either with a heavy copper slug or sleeve is required to hold after initial saturation when its circuit is interrupted during impulsing. The current and flux curves are shown in Figs. **2** (*a*) and **2** (*b*), Sheet IV., for the case of a relay fitted with a sleeve and a slug respectively. The difference in the current curves is of interest, as it shows the closeness of the coupling between the sleeve and the winding, as compared with the slug. The flux being almost completely linked in the former case, the current can rise instantaneously to a large fraction of its full value, while in the latter case logarithmic rise is necessitated by the considerable leakage flux. The completeness of the linkage between winding and sleeve is also well shown in the record of flux. The curve at each break is continuous, indicating a complete transfer of the M.M.F. of the winding to the sleeve instead of a sudden drop due to the disappearance of the leakage flux as in the case of the slugged relay.

It will be seen that for both slugged and sleeved relays the flux at the end of the first break is higher than at the end of the second, but no further marked decrease is noticeable for succeeding breaks, even allowing for slight drift of the spot due to the finite time constants of the integrating unit and the couplings of the amplifier.

Interference.—The apparatus was used in a laboratory where inductive disturbances were considerable and it was found impossible to eliminate this with the present apparatus in all cases. The

most serious type of interference, however, was that arising from the apparatus under test when the conditions were such as to produce a high inductive E.M.F. This E.M.F. occurs necessarily at an important instant in the flux curve and therefore has a masking effect on the flux record. The use of screened leads, spacing the amplifier and the apparatus under test and the use of an earthed search coil, minimised these effects.

. . . . . .

Although the foregoing is mainly concerned with the operation of telephone relays, the method itself should be of wider interest since the necessary amplifier and integrating circuit may be regarded as a useful oscillograph accessory which widens still further the scope of this already indispensable instrument.

The above work was carried out in the Engineering Research Laboratories of the G.P.O. at Dollis Hill.

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM.

TELEPHONES AND WIRE MILEAGES, THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 30TH JUNE, 1931.

No of Telephones owned and maintained by the Post Office.	Overhead Wire Mileages.				Engineering District.	Underground Wire Mileages.			
	Telegraph.	Trunk.	Exchange.	Spare.		Telegraph.	Trunk.	Exchange.	Spare.
719,538	593	3,941	52,899	130	London	25,436	107,399	2,872,004	58,552
96,800	2,227	21,282	72,676	3,149	S. Eastern.	4,169	73,942	314,243	29,349
101,062	4,446	34,310	71,155	3,998	S. Western.	23,176	22,117	228,850	66,792
82,192	6,247	40,206	75,718	7,195	Eastern.	24,683	52,259	177,682	60,106
113,465	8,555	47,006	69,480	4,819	N. Mid.	36,075	77,434	297,603	91,490
100,959	4,785	32,458	84,883	4,047	S. Mid.	15,000	43,546	256,805	88,617
64,762	4,456	30,612	63,178	3,587	S. Wales.	8,006	34,889	153,568	64,117
124,918	7,965	27,473	60,183	4,603	N. Wales.	14,312	42,423	352,723	132,676
176,330	1,369	15,748	46,076	3,286	S. Lancs.	15,541	95,943	569,460	64,556
105,904	6,094	30,674	53,163	3,813	N. Eastern	16,316	58,370	289,535	64,998
71,904	3,786	23,546	42,784	3,173	N. Western.	8,970	39,502	194,185	39,710
55,304	2,434	16,464	29,283	3,187	Northern.	9,432	26,198	154,466	32,315
25,697	4,385	9,673	15,658	708	Ireland N.	145	3,129	59,629	2,681
76,543	4,594	28,364	45,137	1,522	Scotland E.	7,838	21,780	172,012	52,021
99,161	7,246	26,018	48,094	1,161	Scotland W.	12,005	32,206	253,431	32,202
2,014,539	69,182	387,775	830,367	48,378	Total	221,104	731,137	6,346,196	880,182
1,991,808	69,142	384,215	820,092	47,184	Figures as at 31 Mar., 1931	217,768	711,636	6,215,565	884,133

TRUNK LINE AERIAL CABLE CONSTRUCTION.

LONDON-BRIGHTON EXPERIMENTAL CABLE.

G. W. Crudduck and W. H. Brent, B.Sc.

As part of the scheme for the introduction of the Demand Trunk Service, it was decided to investigate the possibilities of 4-wire repeater working over aerial cables having conductors of 10 lb. gauge. The London-Brighton route was selected for the trial, and it is thought that a description of the methods employed in adapting the line to the carrying of an aerial cable will be of interest to many readers of this Journal.

The route was first carefully examined and it was decided to lay the cable underground from London to a point near Coulsdon. From this point to Redhill the existing trunk route was suitable for the aerial cable, but through Redhill the open route consists of steel poles in the footpath without proper staying facilities, and the cable was run underground for about two miles to Earlswood Common from whence it was continued overhead to Patcham near Brighton, with the exception of " Grid " Power Crossings and the lead-in and out for the repeaters at Crawley Exchange. From Patcham the underground route was used to Brighton Exchange. An advantage of aerial construction using lead-covered cables is of course that changes can be made from underground to overhead without having any effect upon the characteristics of the circuits.

The overhead trunk route carried, in addition to trunk circuits, a number of junction and subscribers wires, and preliminary work consisted of diverting the trunk circuits to spares in the existing London-Crawley-Brighton underground system and rearranging the remainder to provide adequate headroom for the aerial cable.

The route generally had to be strengthened by the addition of a number of stays and struts, which involved the procuring of a considerable number of wayleaves. As, however, the breaking stress of the suspension strand, upon which the staying required at angles depends, is 12 times that of 150 lb. copper wire, the release of the existing trunk wires reduced to a certain extent the expense of providing stays.

Design.—It was necessary that the aerial cable construction should conform as far as possible to the standard design for this type of route, described in the Technical Instructions for Aerial Lines. These specify for use with cables up to 1.5 lbs. per foot a main Suspension Strand of 7/14 Steel Strand Wire. A calculation of the factor of safety under a wind load of 50 m.p.h. with $\frac{1}{4}''$ thickness of ice gives a factor of 2.34 on a 60 yard span, the weight of this cable being 1.31 lbs. per foot run and as a factor of 2 is regarded as satisfactory, the standard tensions were used for spans up to 65 yards. The following table gives the unloaded tensions of the main strand for various temperatures, together with the tensions and dips which result in a 60 yards span when the cable is in position. The minimum breaking weight of the strand is 5700 lbs.

Temperature.	Unloaded Tension.	When carrying 37 quad 10 lbs. cable.	
		Tension.	Dip.
20°F.	1020 lbs.	1850 lbs.	37.0 ins.
40 ,,	890 ,,	1800 ,,	38.5 ,,
60 ,,	760 ,,	1750 ,,	40.0 ,,
80 ,,	640 ,,	1650 ,,	41.5 ,,
100 ,,	510 ,,	1600 ,,	43.0 ,,

In the case of spans exceeding 65 yards a "Long Span" construction was adopted. This consists of the addition of an auxiliary strand attached to the poles at a suitable distance above the main strand attachments and clamped to the main strand in the centre of the span. Fig. 1 illustrates this method. The problem was to calculate the tension in the auxiliary strand

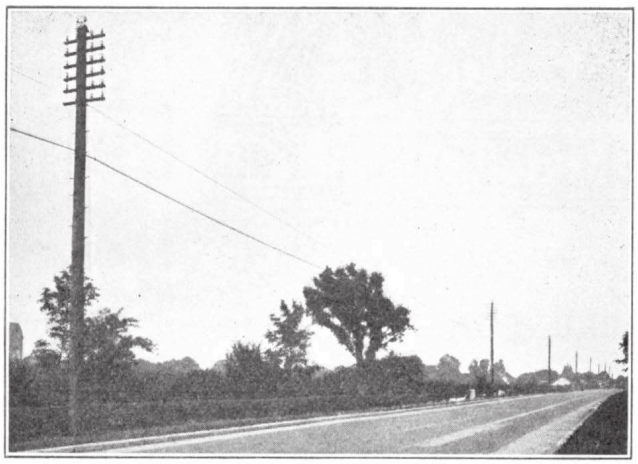


FIG. 1.—LONG SPAN CONSTRUCTION.

when the centre clamp is maintained level with the brackets holding the main strand, and to select a size of strand and separating distance at the poles so that a satisfactory factor of safety is given. With the assumed storm load already referred to, and a separation at the poles between strands of 4 feet, it was found that a 7/12 auxiliary strand wire was required to give a factor of safety of more than 2 and this was therefore worked to generally. In a few cases where the length of span exceeded 75 yards the separation between the Main and the Auxiliary strands at the pole was made 5 to 7 feet. Fig. 2 shows a 90 yard span at Merstham for which 7 feet separation was given. Often, spans below

FIG. 2.—A 90-YARD SPAN AT MERSTHAM.

65 yards occurred among a series of 65-70 yard spans and in these cases long span construction was followed to retain continuity, so that such sections run for several miles. A further problem was to provide data for the erection of the auxiliary strand unloaded and in order not to complicate matters for the construction men unduly, one set of tensions to suit all spans had to be given. This results in the centre clamp being rather high for shorter spans and rather low for the longer spans in a section. Measurements on the route after the cable was in position showed that the centre point was with a few exceptions within 6 inches of the correct position and indeed the general aspect of these portions of the route indicate that considerable success was obtained. Apart from the improved appearance of the line it is anticipated that this type of construction will increase the life of the cable by reducing the swaying action of winds. The reduction of the sag of the cable to approximately 2 feet is also a useful advantage.

The cable itself was manufactured by Messrs. Johnson & Phillips and the Pirelli-General Cable Company, who provided the London - Crawley and Crawley-Brighton portions respectively. The sheath is of lead alloy containing approximately 0.8% of Antimony to resist vibrational stresses. The core of paper-insulated 10 lb. conductors is laid up in star quad formation, for which the area occupied by the conductors is some 40% less than the corresponding multiple twin type, thus giving a much more compact cable. This is an important point when aerial working is considered as the weight is less and the area exposed to storms is less for the same number of wires. The diameter of the 37 quad cable is 0.82 inches.

Except for the steel cable rings the fittings were of standard pattern. Fig. 3 illustrates the Bracket which grips the main strand and which is attached to the pole in all cases by a $\frac{5}{8}$" double-ended bolt, thus providing for the erection of an additional cable later if required. The figure also shows the 3-bolt bracket used to carry the 7/12 auxiliary strand and a splice in the main strand where the wire is taken round thimbles and held by two 3-bolt clamps on each side.

CONSTRUCTION WORK.

Boring poles for Brackets.—About 32 miles of pole line had to be bored to take the $\frac{5}{8}$" bolts and as the completion of the cable was a matter of some urgency a mechanical means of boring was introduced, in addition to hand boring with augers. After consideration of electric and other means of transferring power, a method using a length of flexible steel shafting sufficient to reach a point 30 feet from the ground was developed. The power was obtained from a 2 H.P. petrol engine mounted in a 1-ton Ford van. Several types of drills were tried and the most suitable was found to be the Irwin twist drill with which a pole could be bored in about ten seconds. The operation required three

men, of whom the driver of the van attended to the petrol engine, whilst one man carried out the drilling operation from a ladder, and the third man took the weight of the shafting by means of a sash line thrown over an arm of the pole. The bolt was then fitted and the bracket added.

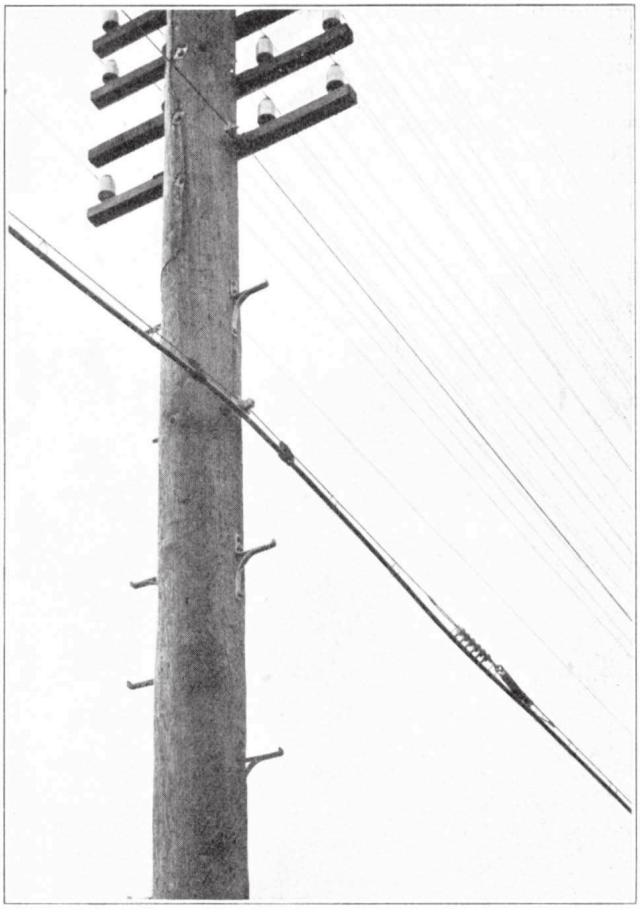


FIG. 3.—BRACKET HOLDING MAIN STRAND.

Erection of Main and Auxiliary Suspension Strands.—The road is one which carries a large volume of motor traffic and particular care had to be exercised in this, as also in the succeeding operation of cabling to comply with the restrictions of the recent Road Traffic Act. The work was allotted to several gangs placed at suitable points along the route between Coulsdon and Patcham, each gang being provided with motor transport for carrying men and stores and aiding generally in the operation. Prior to the commencement and in addition to written instructions which were issued, the foreman of each gang was instructed in the methods to be adopted by the erection of a half-mile section of strand on a convenient portion of the route. The method to be adopted depends entirely upon the obstructions met with, such as road or power crossings, trees and stays which interfere with the raising of the strand to the brackets, but in all cases the wire drum containing half a mile of strand was set up at one end of the section. In straight sections it was economical to run out the strand wire with the aid of a 30-cwt lorry by an attachment at the rear of the vehicle, but many cases occurred where bends in the road or the obstructions already referred to prevented this and the wire was run out by hand. The wire was then lifted into position in the brackets and the tension applied by means of blocks and tackle. With the correct tension on the strand, the nuts and bolts of the brackets and clamps were tightened, and as it was found in practice that owing to the strands compressing under tension the nuts became loose, it was found important to retighten splices and terminations made before tension was applied.

The tension was determined by an oscillation test. As the tension of the wire can be obtained from the length of span, the mass per foot of the wire and the time of vibration, tables were constructed giving the correct times for 40 oscillations and, in view of the varying lengths of span existing, these were made to show the variation from 55 to 65 yards for the same tension in case a 60 yards span was not conveniently available. When making an oscillation test, the best method was found to be for a man stationed on the pole at one end of the chosen span to strike the strand with his hand a few feet from the bracket. The succeeding vibrations at this point were readily discernable and well maintained. The following tables were used :—

UNLOADED TENSION OF 7/14 MAIN SUSPENSION STRAND. BREAKING WEIGHT 5,700 LBS.

Temperature.	Unloaded Tension.	Time for 40 oscillations.		
		55 yds.	60 yds.	65 yds.
20°F.	1020 lbs.	27.6 secs.	27.6 secs.	29.6 secs.
40 ,,	890 ,,	27.1 ,,	29.6 ,,	32.1 ,,
60 ,,	760 ,,	30.0 ,,	32.8 ,,	35.5 ,,
80 ,,	640 ,,	32.1 ,,	35.0 ,,	37.0 ,,
100 ,,	510 ,,	35.8 ,,	39.1 ,,	42.3 ,,

UNLOADED TENSION OF 7/12 AUXILIARY SUSPENSION STRAND WITH 4 FEET SEPARATION BETWEEN MAIN AND AUXILIARY BRACKETS. BREAKING WEIGHT 8,700 LBS.

Temperature.	Unloaded Tension.	Time for 40 oscillations.	
		65 yard span.	70 yard span.
20°F.	1730 lbs.	30.0 secs.	32.2 secs.
40 ,,	1530 ,,	32.0 ,,	34.2 ,,
60 ,,	1310 ,,	34.5 ,,	37.0 ,,
80 ,,	1100 ,,	37.5 ,,	40.5 ,,
100 ,,	930 ,,	41.0 ,,	44.0 ,,

When applying tension, extra stress is required to

counteract any give in the strand or the line itself, and the times for 40 vibrations were made at least 4 to 5 seconds shorter than those given in the tables before gradually slackening until the correct time was reached. At true terminations a loss of tension may occur, and to allow for this a deduction of about 2 seconds from the times given may be necessary when testing the last length of a section.

Ring Placing.—The steel rings, which were of the type known in America as the " National " ring, grip the strand securely and are placed by hand from a travelling chair at 20-inch intervals, so that in effect they form an aerial duct for the cable to be pulled into. For pulling the draw-rope into position a sash line had to be left in the rings during this operation and two methods of doing this were considered. Either the line could be pulled in by attaching it to the bosun's chair as it proceeded along the strand, or it could be run out for a cable length and placed in position first of all by a ring near each pole. The latter was deemed to be the better way and was used throughout. The sash line was enclosed by each ring as it was fitted by the men and the accurate spacing of the rings was obtained by a marked horizontal wire attached to the framework of the chair on the right-hand side. Fig. 4 shows a man in the act of placing a ring and it will also be seen that a supply of rings sufficient to complete one span was carried upon a triangle of stiff wire hanging from the chair. It was found in practice that the men propelled themselves to the centre of a span without difficulty, but in the upward climb near the next pole assistance was required from a man on the ground pulling on a sash line attached to the chair. The men " ringing " soon adapted themselves to their somewhat novel surroundings and became quite expert in the placing of rings, a good average in the span being 10 to 12 rings per minute.

A peculiar and somewhat troublesome effect was observed in the rotation of the strand wire as the chair travelled the span. This caused rings already placed to revolve so that often on completion of a span rings were found to have reached the vertical above the wire or even beyond. Later this led to difficulty in bringing the draw rope into place owing to the increased friction with the sash line riding in the neck of the ring. It is possible that if the draw rope were erected direct in the rings without the use of sash line the weight of the rope would minimise the rotation of the rings, as well as effect a direct saving of the cost of replacing the sash line by rope before the cabling work is done. This will of course involve a large issue of draw rope or require the ringing party to work just ahead of the cabling party.

In the case of Long Span construction the connection between main and auxiliary strands by means of a 3-bolt clamp was made at this stage by a man travelling on a bosun's chair along the top strand so that his weight caused the wire to sag and made the attachment of the clamp a simple matter. This was found more practicable than working from a ladder and pulling the strands together by a sash line passed round them.

Erection of the Cable.—The cable was requisitioned in scheduled lengths so that each joint would be near to a pole. Each length was approximately 500 yards, including a margin for dip and jointing. The intended organisation was for the cable drums, each containing one length, to be located correctly along the route in sequence so that it would be possible to draw in the cable at a fairly rapid rate. Owing, however, to certain cable lengths failing to pass works inspections, sequence could not be strictly adhered to and it was necessary to alter the arrangements to meet the cable deliveries.

Fig. 4.—Workman fitting Rings.

Two cable gangs were employed, each provided with transport, and the work proceeded towards Crawley from Coulsdon and Brighton respectively.

The drums, which had previously been off-loaded at the scheduled pole, were jacked up in position at a suitable distance from the pole and snatch-blocks attached to a temporary rope stay guided the cable to the rings. At the other end the draw-rope was led to the ground-line of the next adjacent pole where a snatch-block enabled the pulling to proceed towards the drum of cable. The rope was attached to the rear of the lorry, which

was run at a speed of about three miles per hour until the last few yards were reached. A complete pull was not always obtained. In congested thoroughfares where footways were crossed by the rope and where side roads intervened or where serious bends in the roads existed, it was necessary for the lorry to proceed towards the drum for a part of the way only, after which it was returned to the starting point for a fresh pull.

The correct lubrication of the cable is an important matter. Too liberal a supply of petroleum jelly with the consequent drippings from the rings in the first few spans besides being wasteful would probably give rise to serious complaints. Cabling with the total absence of jelly was tried, but the friction and the chattering of the rings when this was done showed that lubrication was necessary. A mechanical greaser with a gland which constricts the jelly to a thin film was loaned by the Standard Telephone Co., but, although useful for underground work, it was found not easily adaptable for aerial work and accordingly a greasing box was devised locally for the purpose. This was a strong wooden box, slotted at each end to enable the cable to be passed through. A short length of rubber hose was passed round the cable where it emerged from the box and regulated the film of grease. The grease box was attended to by one man, who was also available at the drum in an emergency. A considerable saving in jelly resulted.

An experiment made during the cabling work was the use of a high speed winch loaned by the Standard Telephone Company. For this a light flexible steel draw rope of $\frac{1}{4}''$ diameter was used and drawing in proceeded at a speed of about $2\frac{1}{2}$ to 3 miles per hour. The winch is mounted on a lorry and is stationary during the operation so that road obstruction problems do not arise. A winch geared so as to be suitable for aerial as well as underground work is being obtained by the Department and it is hoped to make an extended trial of it on this type of work as soon as possible.

Mention should be made of occasional displacements of rings, both during the introduction of the draw rope into the rings and during actual cabling operations. Modifications had to be made to the cable grip by removing the thimble from the eye of the standard $1''$ grip and fitting a special swivel and link. Care in the preparation of the grip was generally repaid by a reduction in the number of rings moved.

Upon completion of the cabling and jointing work it was found necessary to overhaul the whole of the route to put on finishing touches, such as the tightening of bolts, attending to stays and fitting "false" terminations. The marline ties to hold the cable at each pole, as shown in Fig. 3, were added and at angles where the cable touched the pole rawhide strip was bound round the lead.

Jointing.—As the joints had to be made some 26 feet from the ground a platform capable of allowing some degree of comfort as well as protection from adverse weather conditions was necessary. Fig. 5 shows the type of structure when in course of erection, and it will be seen that painters' cripples on the ladders carried the planks which constituted the jointer's seat and tool bench. The pieces of timber projecting upwards and that across the top of the ladder or, alternatively, the auxiliary strand where it existed formed supports to which a tarpaulin could be made fast to shield the platform from wind and rain.

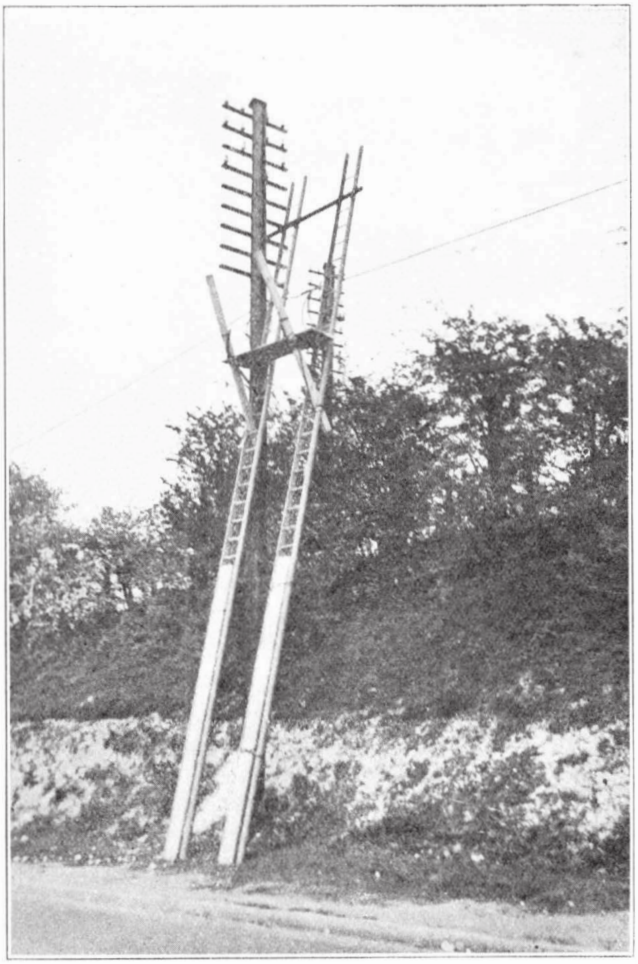


Fig. 5.—Erection of Jointing Platform.

To maintain the insulation of the cable special precautions had to be taken. A drying oven was made locally to fit over strand and cable. (Fig. 6). The blow lamp at the base of the oven and about one foot below the joint maintained a good supply of hot air in the top of the oven, and a small door beside the joint enabled the jointer to ascertain the state of the cable.

All joints were made to a "Systematic" jointing schedule specially prepared for this type of cable with the object of dispensing with cable balancing tests. This was applied at all joints, with the exception of a straight joint on one stub of each loading coil pot and certain crossed joints to secure agreement in numbering of the pairs.

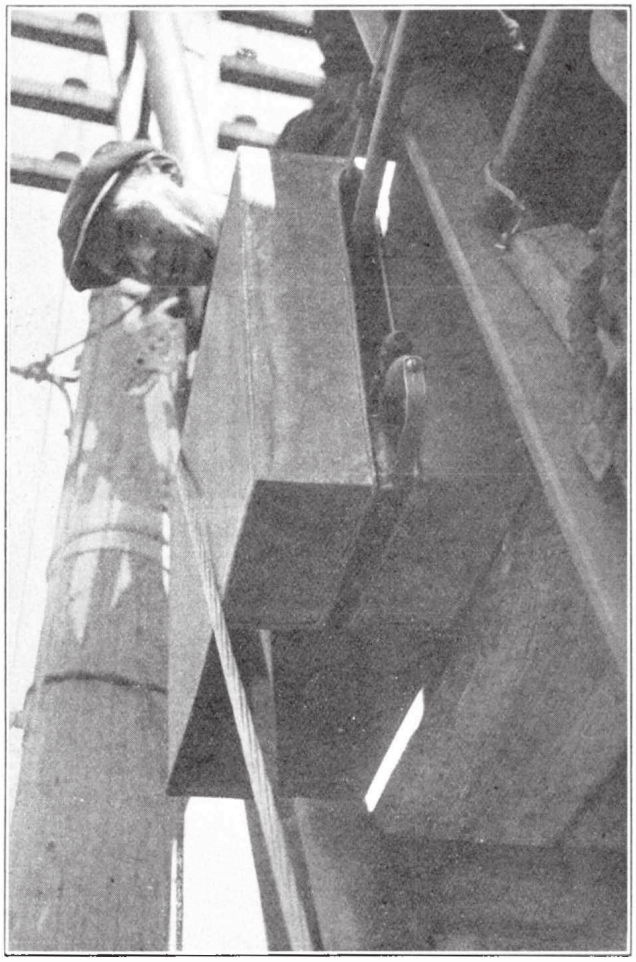


FIG. 6.—DRYING OVEN.

Loading Coil Pots.—The pot provided for the aerial section of the route was attached to the poles. It was fixed to the field side of the pole upon special brackets in a position two feet below the cable. Tackle was used to lift them into position on the brackets and they were made fast to the pole by steel straps. This work was carried out by a gang of four men with motor transport.

The position of the joint gave rise to some discussion, as there appeared to be some benefit in having the joints secured to the pole vertically above the pot, but the position occupied by the normal type of joint between cable lengths, that is to say, suspended horizontally from the strand near a pole, was, however, that adopted. Every joint, whether at a loading coil or at a through cable position, is supported by marline ties at the centre and on each side of the sleeve.

The general appearance of a pole carrying a loading coil pot can be judged from Fig. **7**. The pot and the fittings are finished with a coat of black paint which prevents the pot from becoming conspicuous.

The jointing of the loading coil stubs to the aerial cable was carried out from a platform made up of 78″ and 48″ arms across which were placed boards and which were supported from the arms on the pole by wire stays. These platforms were, of course, intended to remain until all testing at these points was completed.

Testing.—Before each loading pot was jointed up tests for insulation and contacts were made between the up and the down stubs, using a 250-volt megger. Each loading coil section was also tested for insulation, conductivity and contacts with a 500-volt megger and cross-talk tests were made. After the loading coil sections had been proved satisfactory, these were joined up in groups of three and nine with re-testing in each case until the cable was complete.

These represent all the necessary tests for the connecting up of the cable. It is an important point that throughout the work no cable balancing tests were made, thus effecting a considerable saving in time as well as a reduction in the cost of providing the circuits.

It was particularly noticeable that after the ends had been opened for testing a short while, even in fine weather, the insulation dropped rapidly and low readings were obtained. This necessitated further

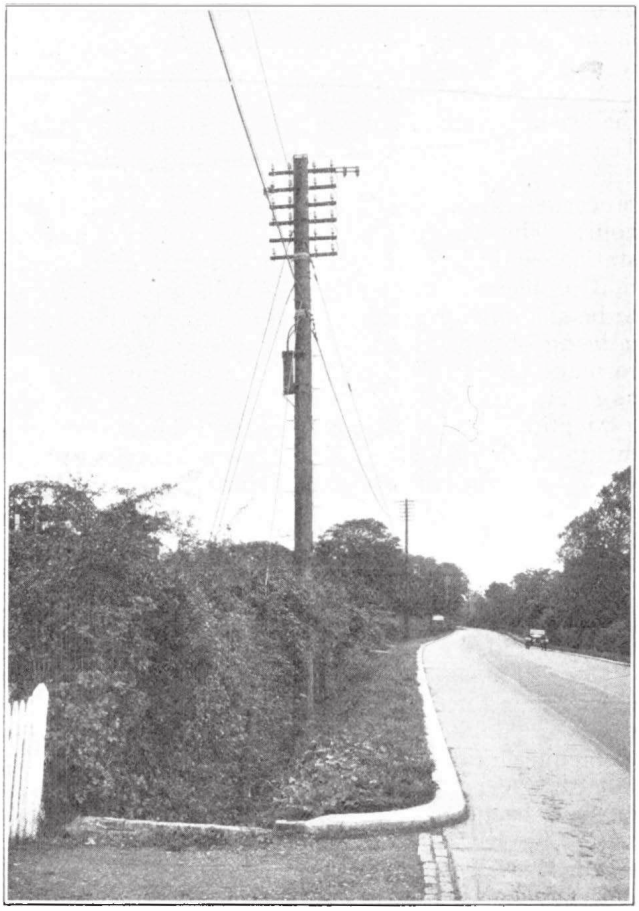


FIG. 7.—LOADING POT ON POLE.

drying out at the open ends of the cable. The exposed position of the joints some 25 ft. above the ground calls for considerably more care in protecting the cable than is the case with underground cables.

Costs.—It is difficult to produce figures for the erection of this type of cable based on the actual expenditure on the present experimental work, as of course much would not recur in future work. It is sufficient to say that the work was recorded in detail as it proceeded and that information has been collected which will be of use in the preparation of further schemes.

In conclusion, it should be recorded that two very able Inspectors supervised the work throughout. The work was well organised and the men were zealous and keen to make the work a success.

COVERED DROP WIRE FOR SUBSCRIBERS' DISTRIBUTION.

A METHOD of using covered wire from distribution poles to subscribers' premises, developed at the Research Station, Dollis Hill, is being tried in various parts of the country. Briefly, the method is as follows :—

A new type of insulated twin wire known as "Cable, rubber covered and braided for drop wiring, one pair, Cadmium Copper Conductors" is cleated from the "Block, Terminal" on the distribution pole to a "Drop wire pole-head"

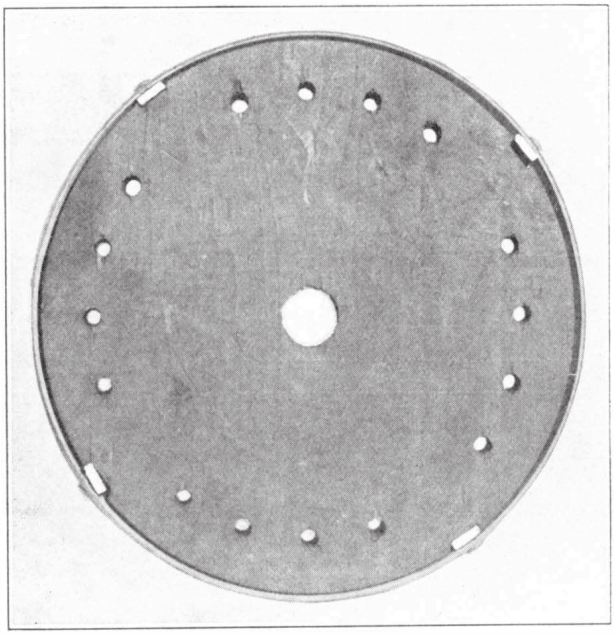


FIG. 1.—DROP WIRE POLE HEAD, SHOWING DRILLINGS FOR CLAMP SPINDLES AND FINIAL DOWEL.

where it passes through an eccentric clamp used for anchoring the wire. From this point the wire goes to the subscribers' premises where again it passes through another eccentric clamp fitted in a suitable fixing. The wire is then cleated on the subscribers' premises direct to the telephone when the span from the distribution pole to the subscribers' premises does not exceed 60 yards, and to the protector when the length of span exceeds this distance.

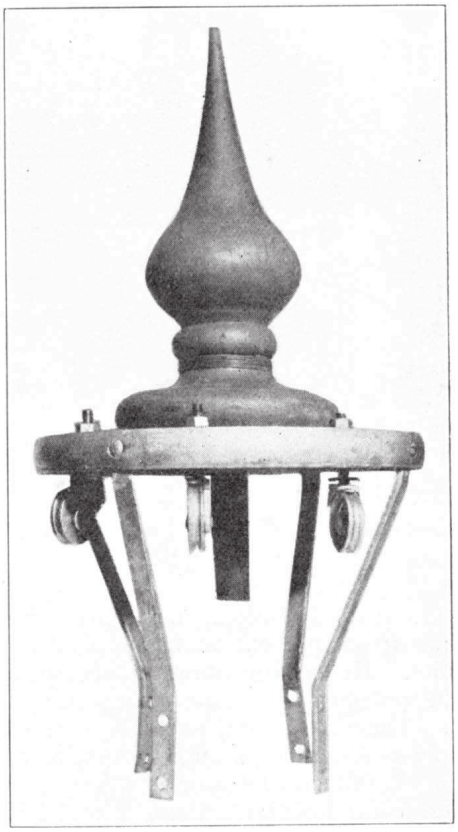


FIG. 2.—FINIAL, CLAMPS AND STAYS.

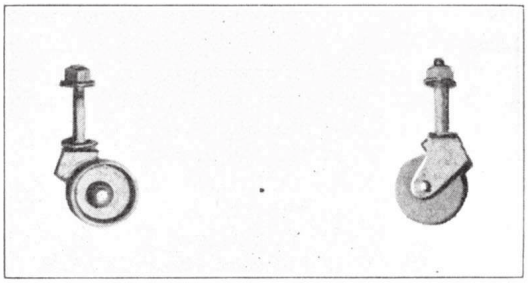


FIG. 3.—ECCENTRIC CLAMP: BOTH SIDES.

The drop wire pole-head, being circular, renders the method most suitable for use in cases where the

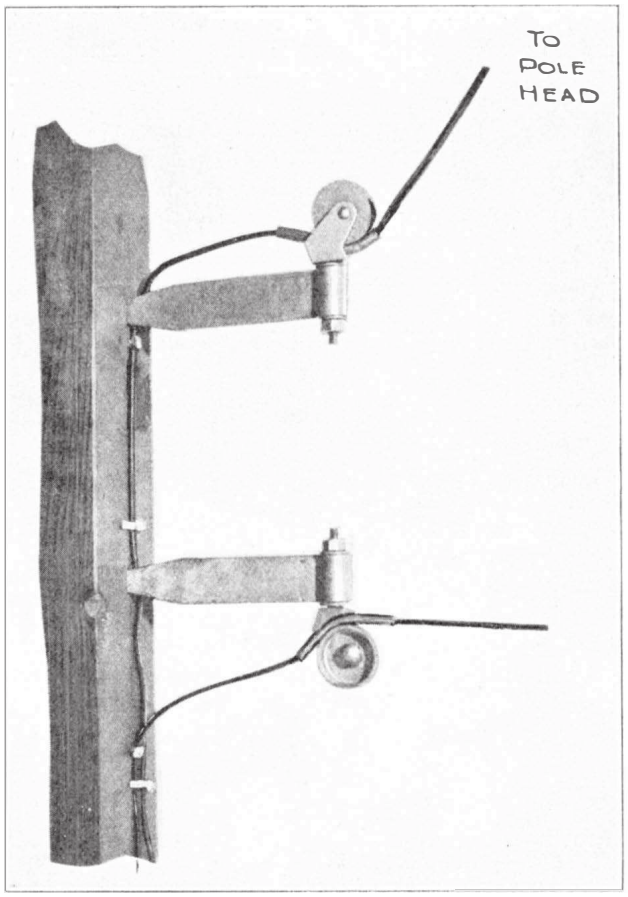


FIG. 4.—SHOWS THE SPLIT LEAD SLEEVE AND METHOD OF FIXING CLAMP.

distribution at the D.P. is of the umbrella formation. Pole-heads are at present being supplied for 16 and 28 circuits. Holes are bored at equal distances round the pole-heads to admit the eccentric clamp spindles. The pole-head is seated on the flat top of the pole and is made secure by the insertion of a pole finial dowel, and by four iron stays, one fitted at each side of the pole. Figs. **1** and **2** illustrate the drop wire pole-head.

The eccentric clamp and the spindle are made up in one piece and Fig. **3** illustrates the item. The clamps at the subscriber's end are used with "Brackets No. 5" and "Spikes No. 1," but, to avoid what would otherwise be a loose fitting, tubular washers cut from E.L. tubing are fitted in the eyes of the items mentioned.

In order to protect the twin drop wire at the point where it is tightened in the clamp and to ensure a more secure grip, a split lead sleeve No. 1 is placed over the covered wire and nipped in with the pliers. The pull of the wire between the pole-head and the subscriber's end pulls the clamp wheel round to the correct clamping position, and when this is found, the nut on the spindle is screwed up tightly. The clamp wheel is tightened by means of a special spanner.

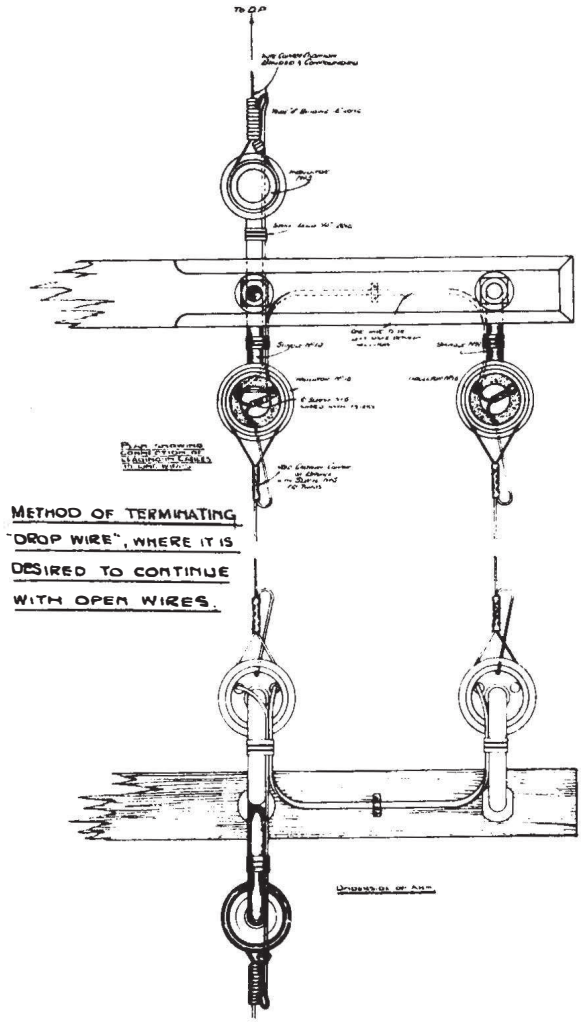


FIG. 5.

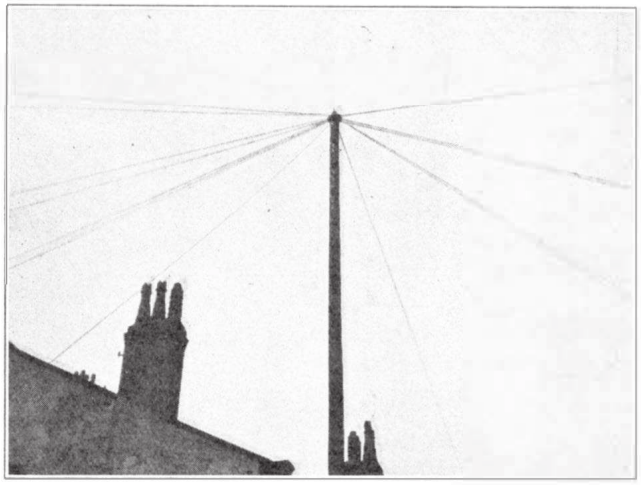


FIG. 6.—POLE FITTED FOR DROP WIRE DISTRIBUTION.

The clamps may be fitted with the eccentric wheel either above or below the spindle according to the

position of the fixing at the subscriber's end relative to the height of the pole-head. If the fixing at the subscriber's end is much lower than the pole-head the clamp wheel should be uppermost in the fixing at the subscriber's end. Fig. 4 illustrates this.

Whilst the method is designed for simple direct drops at distribution poles with umbrella distribution, it can also be used conveniently and economically in cases where there is an intermediate pole or other fixing between the distribution pole and the subscriber. A method of dealing with a case of this kind is illustrated in Fig. 5. A covered drop wire distribution pole is shown in Fig. 6.

The success of the method will largely depend upon the behaviour and life of the drop wire.

J.E.F.

THE HOT WIRE GAS LEAK INDICATOR.

General : C. E. RICHARDS, A.I.C., Dollis Hill.

SHORTLY after the events of December, 1928, when an explosion occurred in a section of the old parcels tube, due to a leak of coal gas, various methods of ensuring the safety of cable tunnels from explosion were considered, and, in addition to the installation of forced ventilation for the remaining sections of the parcels tube, the provision of an automatic system for giving warning of the presence of inflammable gases was thought desirable.

A number of schemes have been suggested from time to time, and several instruments are in fact on the market. It was seen, however, that none of these schemes was quite suitable for the purpose, and the problem of designing an instrument specially suited to Post Office requirements was undertaken by the Research Section.

Briefly, these requirements are as follows :—

1. The instrument should be sensitive to all probable inflammable gases when they are present in amounts considerably below the lower explosive limit.
2. The instrument should be capable of operation on one of the commonly occurring Exchange battery voltages.
3. The line current should be kept as low as possible so that ordinary telephone conductors may be utilised if necessary.
4. Maintenance should be reduced to a minimum.

It was assumed that the instrument should operate electrically.

There are various methods which may be used to detect the presence of inflammable gases, these being based on the physical or chemical properties of the gases. The methods which depend on the physical properties of the gases are not in general so reliable as those based on the chemical behaviour. For example, the common gas leak indicator operates because gases of different molecular weights diffuse at different rates through a porous diaphragm. The lighter the gas, the more rapidly does it diffuse. For detecting the presence of coal gas in air, this instrument is quite satisfactory for amounts over about 0.5%, since coal gas is distinctly lighter than air, *i.e.*, it has a lower average molecular weight than air. If, however, we take the case of another commonly occurring inflammable gas, petrol vapour, which is distinctly heavier than air, having in fact an average molecular weight about twice that of air. Thus, petrol vapour is shown by a gas leak indicator as a heavy gas, and coal gas as a light gas. It is quite conceivable therefore that an explosive mixture of these gases and air could be tested with a gas leak indicator and show the presence of little or no foreign gas. There are other methods which depend on the physical properties of the gases, but they suffer from similar disadvantages. They are quite satisfactory when working in mixtures of gases of known qualitative composition, and can be used to determine their quantitative composition quite satisfactorily.

An example of this type is the Shakespear Katharometer (B.P. 124453/1916) which was used successfully for testing hydrogen for balloons. This apparatus depends on the different thermal conductance rates of gases.

There is only one universal property of inflammable gases, and that is their property of releasing energy as heat when they are burned. The amount of heat liberated by equal volumes of different gases is not the same; for example :—

Hydrogen—$H_2 + O = H_2O$ (liquid) + 68.4 Cals.
Carbon Monoxide—$CO + O = CO_2$ + 68 Cals.
Methane—$CH_4 + 2O_2 = CO_2 + 2H_2O$ (liquid) + 211 Cals.
Benzene—C_6H_6 (gaseous) + $9O_2 = 6CO_2 + 3H_2O$ (liquid) + 770 Cals.

It will be observed that in all the above reactions heat is liberated, so that if we can find some means of measuring the heat evolved in burning inflammable gases, although we shall not be able to determine them quantitatively without calibrating the apparatus, yet in no case is it possible for an inflammable gas mixture to fail to give an indication of its presence, because they invariably evolve heat on combustion.

The method adopted in this case to measure the heat evolved is to burn the gases quietly at the surface of a heated platinum wire, and to measure

the increase in resistance of the wire due to the heat of combustion. There are a few wires, such as platinum and palladium, which possess the property of causing gases to burn at their surface catalytically at low temperatures, no matter what is the concentration of gas. Other metals, such as gold, will only cause combustion in a definitely explosive mixture and at a comparatively high temperature.

The method actually used in the hot wire gas leak indicator is to make the platinum wire which causes combustion, one arm of a balanced Wheatstone bridge. If the bridge is balanced in the absence of inflammable gas, as soon as any comes into contact with this wire it will cause the temperature to rise and unbalance the bridge. Since the amount of heat liberated on combustion is strictly proportional to the amount of gas burned, for low concentrations of gas the rise in temperature of the wire will be proportional to the concentration of inflammable gas, and thus the amount of unbalance of the bridge is a measure of the concentration of gas.

The actual circuit used is shown in Fig. 1. It will be seen that it consists essentially of a Wheatstone bridge, two arms and part of the third being accommodated in the home end set at the Exchange, the remainder of the third and all the fourth being outside the Exchange. It is necessary to use line wires as part of two arms, instead of the more convenient way of making them part of one arm only, in order to compensate for air and earth temperature changes. The circuit is balanced originally by means of tapped resistances across the peak of the bridge. In place of the usual galvanometer, a modified Weston Model 30 relay is used to detect the unbalance of the circuit. This instrument has a resistance coil of 300-400 ohms and can readily be set to operate at any stated unbalance.

General Description of Apparatus.—The general appearance of the apparatus can be gathered from Figs. **2** and **3**. As far as possible the parts used in the circuit are standard Departmental issue, so that spare parts will be readily available. In the instal-

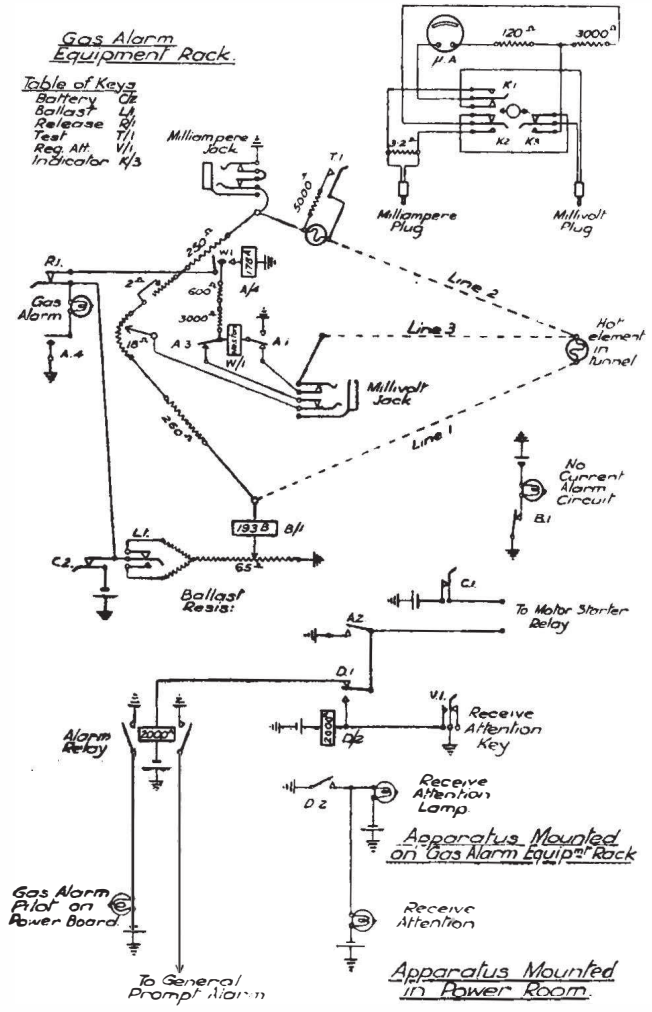


FIG. 1.—HOT WIRE GAS LEAK INDICATOR. CIRCUIT DIAGRAM.

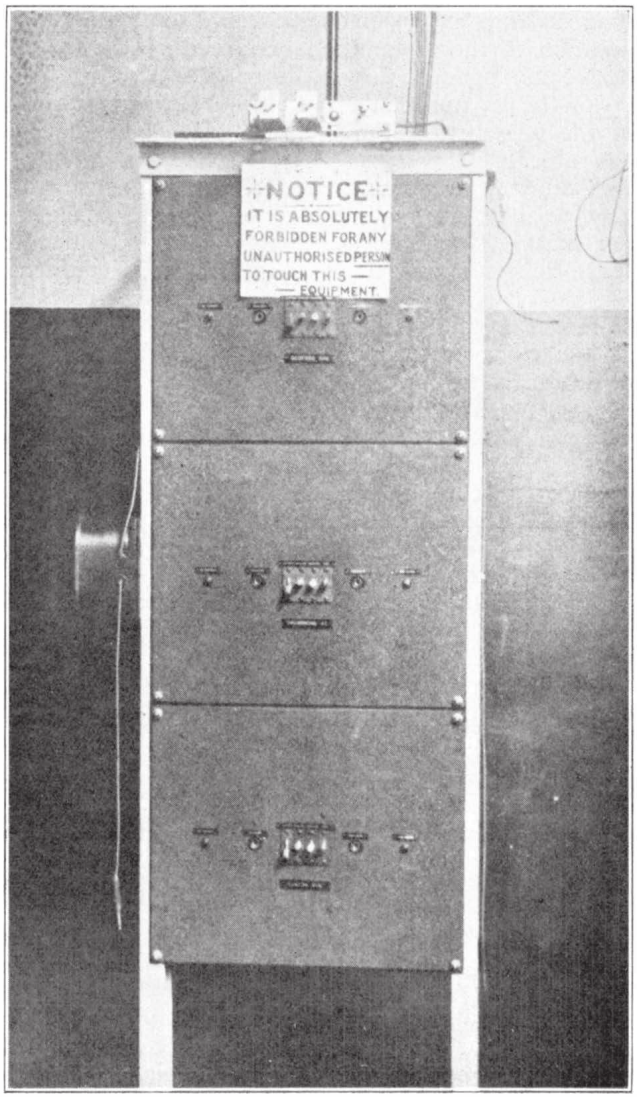


FIG. 2.—THREE SETS MOUNTED ON RACK. COVERS ON. SHOWS ALSO DETECTOR, PLUGS AND CORDS.

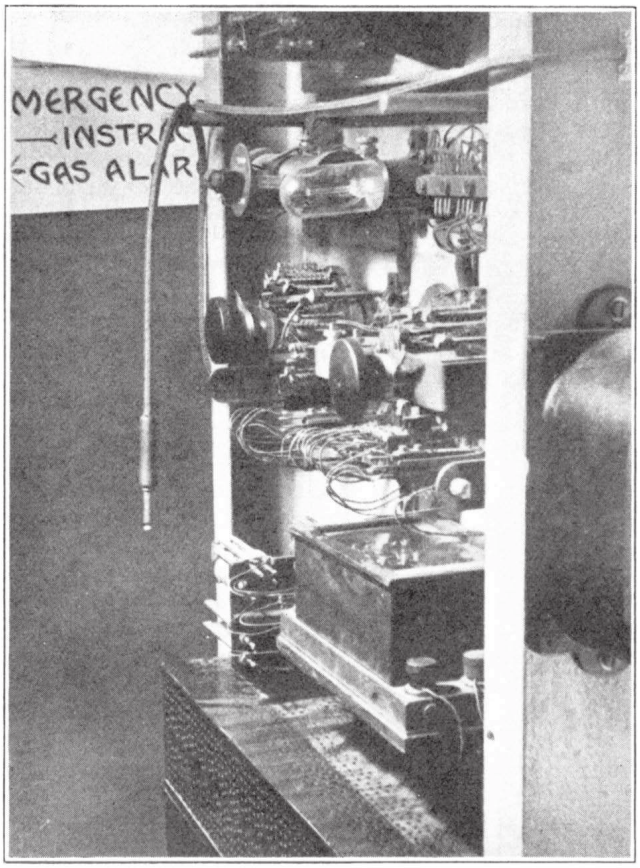


FIG. 3.—ONE COVER REMOVED TO SHOW CLOSE-UP OF ONE SET.

lations already made, three sets have been mounted on each rack, but, as they are quite independent, any number can be installed without mutual interference. The apparatus is designed to work from the 50 volt Exchange battery. The voltage limits of this are 46-52 volts and in order to maintain the bridge feed constant, the actual feed is taken from a 65 ohm potentiometer which is maintained at constant current by means of an Ediswan ballast resistance (" barretter "). This consists of an iron wire in a bulb of low pressure hydrogen, and was specially manufactured by Messrs. Ediswan to compensate for a voltage change of 8 volts and to give over this range a constant current of 0.7 amps. The current-voltage characteristic of this type of ballast is shown in Fig. 4. Two alternative circuits are provided in each bulb, so that should one fail it is not immediately necessary to replace the bulb, but a temporary re-instation of service may be made by switching on the set after throwing the key on the front panel which is labelled " ballast." Current from the potentiometer is fed to the bridge through a relay 193B, which is arranged to operate a lamp circuit when the current drops below working range, and thus indicates when an element has burned out or the current to the bridge has for any reason failed.

The actual bridge consists of four arms, two of which are resistance coils of 250 ohms, the other two being fine platinum wires supported in a mechanical bridge of glass. The wire used for these elements is 0.0005" diameter. Two hot elements are used, one at the home end and one in the tunnel, the one at the Exchange being to compensate for temperature changes and any current changes which occur due to the ballast characteristic not being quite horizontal over the working range. The advantage of this double compensation is that whilst perfectly matched hot elements would compensate entirely for current and temperature changes, without the introduction of the ballast, the use of the ballast enables sufficient compensation to be obtained using only roughly matched elements, thus saving a considerable amount of testing. Incidentally the use of the ballast ensures such a constancy of current that the hot elements may be set working at the

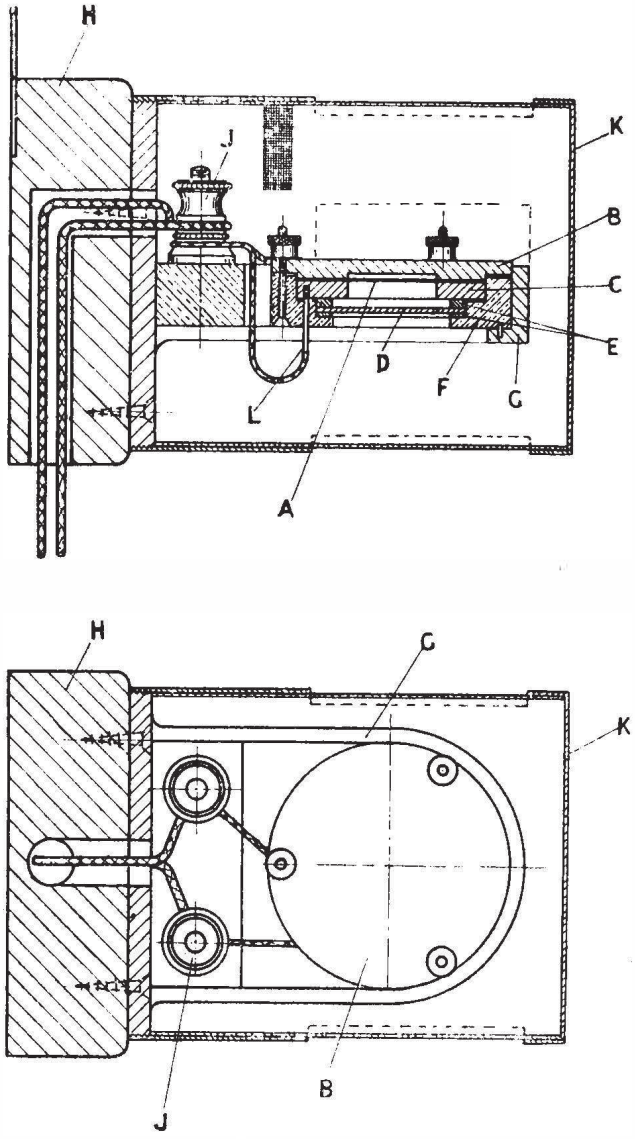


FIG. 4.—ELEMENTS OF INDICATOR.

optimum current for efficient gas detection and long life.

These hot elements are housed in cases shown in Fig. **4**, the respective parts being :—

A. Hot element.
B. Upper contact plate.
C. Lower contact plate.
D. Porous (alundum) diaphragm.
E. Rubber sealing rings.
F. Ebonite container.
G. Brass bracket.
H. Wood (teak) base plate.
J. Terminals.
K. Outer canister with gauze windows.

Parts A-F are held together by nuts and bolts, the whole system being rendered tight by pressure against the rubber sealing rings.

To complete the bridge the two 250 ohm arms are joined by two stepped resistances of 18 ohms and 2 ohms respectively. By adjustment of these resistances it is possible to compensate for the different resistances of the various hot elements, and balance the bridge within about 1 millivolt.

When the bridge goes out of balance due to the presence of inflammable gas, the Weston Model 30 relay, which locks itself in and also operates relay A/4. When relay A operates the following things happen :—

1. A signal is sent to the main alarm circuit.
2. A lamp is lit on the particular set operating.
3. The fan in the cable tunnel is started.
4. The Weston relay is disconnected from the line.

This state of affairs is maintained until the set receives attention.

The signal to the main exchange alarm is not taken directly, but through a relay which is connected to a non-locking key. If, when the alarm has operated, this key be thrown the signal is transferred from the general prompt alarm system to silent warning lamps in the power room and on the set rack. The set can be momentarily put out of action by throwing the key on the panel marked " Release " [R.I.]. When the fan has been running for some time after the receipt of an alarm signal, the " Release " key is thrown. It is a non-locking key, and on its restoring, the set is again in an active condition to detect gas, and if there is still gas around the active element it will operate again, starting the fan, etc., just as before.

Facilities are also provided for testing the operation of the whole set by throwing the key on the panel marked " Test " [T.I.]. Since the presence of inflammable gas at the active element causes its resistance to rise, this condition may be simulated for test purposes by shunting the inactive element. Throwing the " Test " key puts a 5000 ohm shunt on the inactive element and operates the set just as though a gas alarm had been received.

Each rack of instruments is completed by a combined millivoltmeter and milliammeter. This is constructed from a Ferranti microammeter connected through suitable resistances and with a key to change the circuits. Connection to the detectors is made by means of plugs.

Performance of the Apparatus.—The sensitivity of the apparatus is affected somewhat by the line resistance as this reduces the relative resistance change due to the presence of gas at the hot element. In designing the outfit it was assumed that 100Ω was the longest line over which it would be necessary to work, and in practice it has been possible to keep the line resistance below this figure. Curves showing the sensitivity of the bridge at various line resistances are shown in Fig. **5**. In this figure also is shown the sensitivity curve of the apparatus working as a Shakespear Katharometer at zero line resistance.

The apparatus has also been tested for operation in hydrogen and petrol vapour and responds to both of them when present in quantities well below the lower explosive limit.

In conclusion the author would like to thank Captain Cohen, of the Research Section, for permission to publish this matter and members of the staff at Dollis Hill for sympathetic co-operation, particularly Mr. H. J. Gregory and Mr. D. W. Glover. The assistance and patience of officers of the London

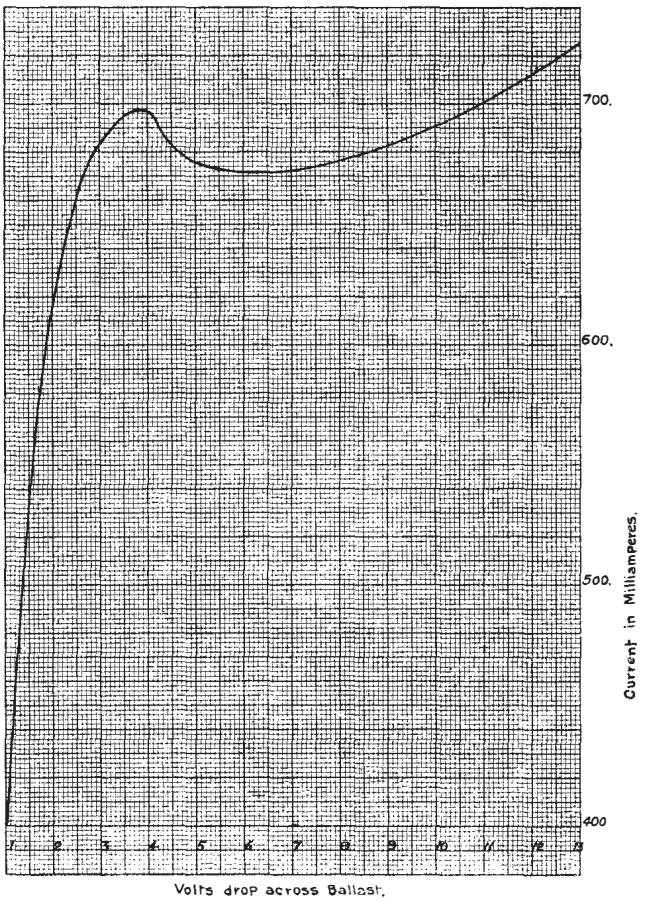


FIG. 5.—CHARACTERISTIC CURVE OF EDISWAN 0.7 AMP. BARRETTER.

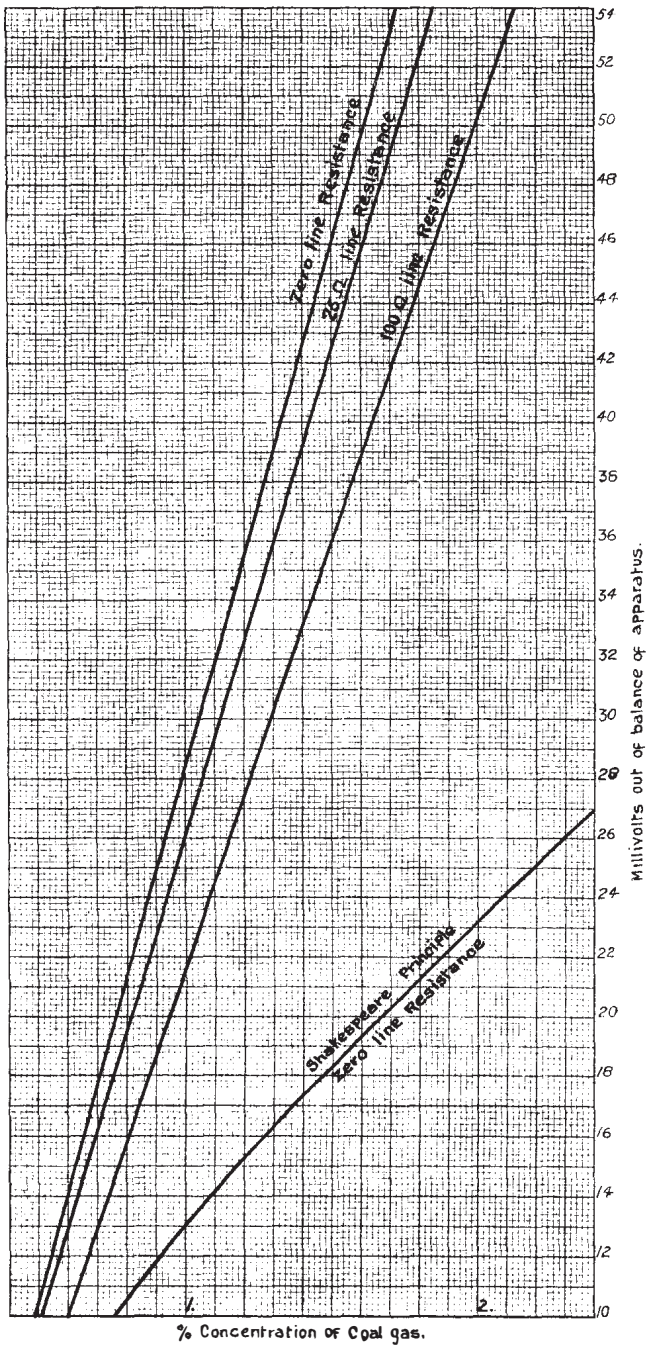


FIG. 6.—RESPONSE CURVES OF HOT WIRE GAS LEAK INDICATOR.

Engineering District during the trial period is also greatly appreciated.

. . . . . .

Details of schemes for detecting inflammable gases are given in the following :—

Philip & Steele. B.P. 3002/1913. B.P. 5467/1913.
Shakespear. B.P. 124,453/1916.
Ringrose. B.P. 267,990/1925.
Weaver and Weibel. Bureau of Standards, Scientific Paper No. 334.

Installation and Practice : G. MOWER, I.C.T. Section.

The rack shown in Figs. **2** and **3** is designed to embody three circuits which are linked with manholes at Bedford Avenue, Euston and Drummond Street, each circuit being quite separate from the other. The various apparatus comprising the circuit is mounted at the back of the panel immediately behind the particular row of keys and lamps. In the cable chamber, a relay set, motor and fan are installed, and also a pressure gauge, by which it can be verified that the fan is actuating properly. Extension bells working in conjunction with the main alarm bell associated with the particular panel are fitted in the exchange switchroom and test room for the purpose of indicating the alarm to the test clerk and exchange supervisor should the panel be unattended.

The apparatus is set to operate at 2% concentration of coal gas. Combustion takes place at a very early stage, and the excess heat due to combustion is communicated to the platinum wire, which causes a further rise in temperature, and consequently a rise in resistance of the element which causes the arms of the bridge to become unbalanced.

Balancing the Circuit.—At this point it would be perhaps best to explain that the circuit has to be " Balanced " before it is possible to put the apparatus into service. To do this we have to have some indication for reading the current flowing through the bridge and therefore we plug our milliamperemeter plug into the milliamp-jack to read any such current that may be flowing.

Special normal currents for the particular circuits have been arrived at, and in the case of Bedford Avenue manhole have been decided at 134 milliamps. Adjustment to the specified current is made by means of the 65Ω potentiometer. When the prescribed current has been obtained, the milliamperemeter plug is removed, and the millivoltmeter plug is inserted into the millivolt jack, the millivoltmeter is then balanced to zero by first using the 18Ω tapped resistance and making a final adjustment with the 2Ω tapped resistance.

Having done this, all plugs are removed and keys set at normal with the exception of the " Battery key," which is kept in the operated position to supply current to the apparatus, which is then ready for use.

Operation for Gas Alarm.—If then an inflammable gas comes into contact with the remote end element, as already explained the heat developed due to combustion causs that arm of the Bridge to become higher in resistance and therefore unbalances the Bridge.

This has the effect of producing a PD across the Weston relay, and consequently a current flows through it. The relay then operates and upon this depends the operation of other apparatus in the

circuit. A special pilot contact of the Weston relay makes first and this provides a locking circuit *via* 3600Ω resistance and the coil of A relay to earth. The second contact operates immediately after, and provides a circuit for the operation of " A " relay, *via* the Release key and Battery key contacts to battery.

When the " A " relay operates, the Weston relay is disconnected from the circuit, but does not fall away when A1 and A3 contacts are broken due to the special construction of the relay, and therefore remains operated; it is then locked in parallel with A to battery. The operation of A also causes the gas alarm lamp to light, *via* A4 contact to earth, the main and extension alarms, and also the motor start relay which operates the motor and fan *via* A2 contact to earth. This operation signals a gas alarm and the attendant carries out his instructions which he has in printed form in a holder adjacent to the plant.

He, first of all, stops the alarm bells ringing, by operating the " Receive Attention key," which is of the non-locking type, and this causes D relay to energise and lock to the earth at A2 contact, thus causing the alarm bell relay to restore to normal. At D2 contact a circuit is made for the Red pilot, Receive attention lamp, which lights and indicates that the attendant is dealing.

Description of the Motor and Fan.—The operation of A relay provides a circuit for the motor start relay, *via* earth at A2 contact and battery at C1, the armature of which is arranged to automatically cause the motor to start up slowly until it attains half speed. If it is desired to increase the speed of the motor so as to expedite the clearance of gas from the manhole, this can be done by operating a hand rheostat which is adjacent to the start relay set. The motor is directly coupled to the fan, and this runs continuously until the manhole is cleared of gas.

The fan acts as a blower and causes fresh air to be forced through the cable tunnel into the manhole concerned, thereby causing the gas in the manhole to be ejected through a grid in the cover of same. The functioning of the fan can be checked by the operation of a pressure gauge, one side of which is connected by means of a rubber tube to the tunnel which goes to the manhole.

Fig. **7** shows the apparatus in question, the fan cannot be seen as it is in the background of the photograph and is enclosed.

The other apparatus can be seen fairly clearly, the pressure gauge being in the centre of the picture between the motor and starter, the rubber tubing only is seen, which is connected to the shaft between the fan and the cable ducts.

Testing the Apparatus.—To enable the apparatus to be tested conveniently it has been arranged for the hot wire element, which is mounted on the panel, to have a 5000Ω shunt placed across it, which is normally disconnected by the springs of the Test key.

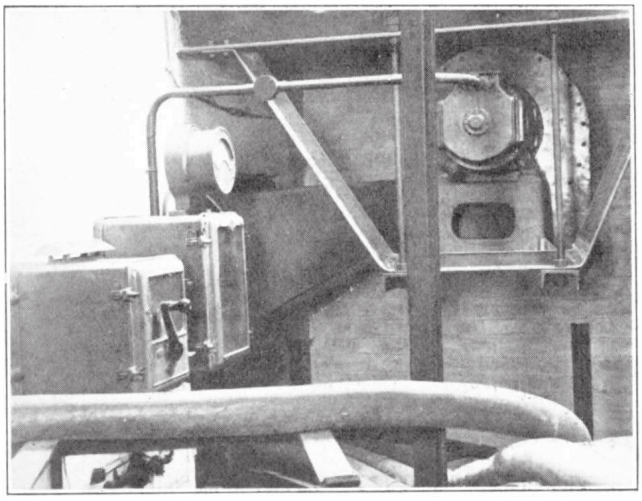


FIG. 7.—GENERAL VIEW OF FAN.

By throwing the Test key which is of the non-locking type, the home end element is shunted, thereby causing the resistance of the arm to alter and unbalance the bridge.

The Weston relay and other apparatus operate as previously described, thus proving the circuit to be in order.

To restore the apparatus to normal, the Release key, which is also non-locking, is thrown and at R1 disconnects the battery, which hold the A and Weston relays locked, thus releasing them, and the circuit is again normal.

No or Low Current.—The " no or low current lamp " is provided to ensure a means of indication should the prescribed current for the particular circuit fall below its rated value.

The lamp is normally out, owing to the B relay being held operated by the current in the circuit.

In considering the apparatus it would be as well to explain that there are two indications of " no or low current " and are due to the following causes :—

1. Fall of current below the prescribed value to a total failure in the upper bridge arms.
2. Fall of current below the prescribed value to a total failure in the lower bridge arms
3. Fall of current below the prescribed value to a total failure in the whole circuit.

The causes of failure that are most likely to be experienced are due to :—

1. Failure of the hot wire element at the remote end, due to burning out or other causes.
2. Failure of the home element due to the same reason.
3. Failure of the main current, due to the ballast resistance burning out.

Other failures due to faults in the ratio arms are not likely to occur, as the apparatus is well protected from outside interference.

If failures do occur in the ratio arms one or two of the alarms will operate.

Operation of Alarms. Case I.—Failure of Remote

end elements. If the remote end element fails or becomes high in resistance owing to its nearing the end of its normal life, the shunting effect of the element to the corresponding ratio arms is altered.

It has been arranged that if the total current in the circuit falls below 30 milliamps the no or low current alarm is given.

Two alarms are received—

(1) The no current alarm due to the B relay falling away, owing to the increased resistance of the circuit, resulting in decreased current, and

(2) The gas alarm due to the Weston relay operating by the current flowing through it in its operative direction.

Case II.—Failure of the Home end element results in one alarm being given and that is the " no current alarm."

A point of interest here is that although the conditions appear to be similar in both cases the gas alarm is not given in Case II.

This can be explained by saying that the Weston relay is designed so as to operate when current is caused to flow through it in one direction only.

Case III.—Failure of the main current in the circuit results in the " B " relay releasing and causing the no or low current lamp to light.

There is no audible alarm given in this case, as it is not provided for, and appears to be a point that requires attention.

Although it is highly improbable that the current will fail, it is possible that the ballast resistance may eventually burn out.

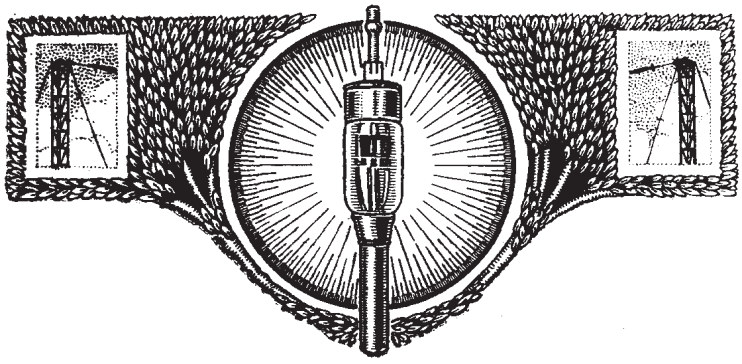
If this should happen, the circuit can be restored by throwing the ballast key in the reverse direction, thus bringing in circuit a spare ballast resistance as shown in the diagram. There is no doubt that the circuit will be modified in the near future so as to give an audible alarm in this case. [*This has now been done.—C.E.R.*]

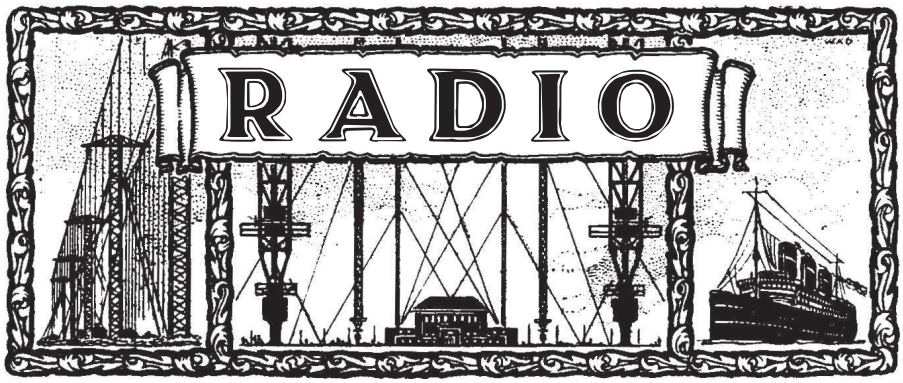
Routining.—A routine test is carried out daily and the apparatus is tested by operating the test key. The motor is allowed to run for two hours and a record is kept of the condition of balance of the circuits, re-balancing being made when necessary.

In conclusion, I should like to add that if a gas alarm is received the gas company are advised and they send their men to the manhole concerned to work in conjunction with the engineering officers.

After normal hours of duty, the gas company are advised and they send out their men with a lorry who pick up two of the Department's officers at their home addresses, proceed to the exchange for tools and thence to the manhole concerned to deal with the trouble.

ERRATUM.—*It is regretted that the name of Mr. Cradduck, joint author of the article beginning on page 213, is incorrectly spelt. The correct spelling is Cradduck.*





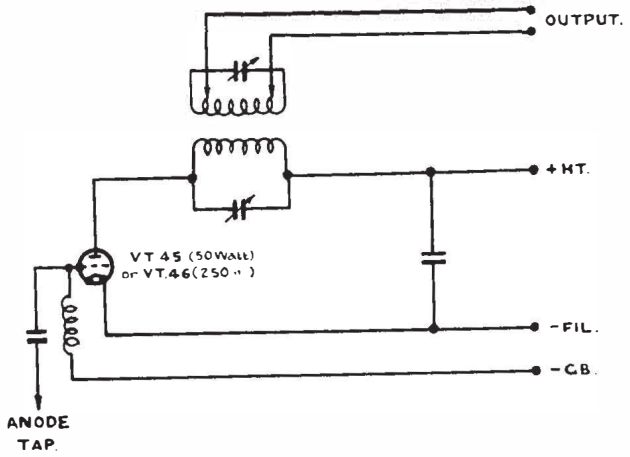
FREQUENCY CONTROL EQUITMENT OF POST OFFICE SHORT WAVE TRANSMITTERS.

E. J. C. Dixon, A.C.G.I., B.Sc., D.I.C.

II.

IN the first part of the article published in the last issue of this Journal an account was given of the quartz oscillators which are the foundation of the system used by the Post Office. The quartz oscillators are operated at frequencies of the order of 2,000 kc/sec and the present article describes the circuits by which the frequency is changed to that of the carrier which is of the order of 10,000 kc/sec. The apparatus described herein is followed by amplifier circuits, which raise the carrier power to 20 kW, which is then conveyed by transmission lines to directional antennæ and radiated in the required direction.

The Frequency Multiplier.—The frequency multiplying circuit is a simple tuned anode circuit with a direct tapped grid excitation from the previous anode circuit usually at half the frequency. (Fig. 11). A value of negative grid bias just less than the peak value of the grid exciting voltage is used so that anode current flows for only half the period of the exciting positive half cycle, and the wave form is such that there is a large component of second harmonic in the anode circuit. Since the anode circuit is tuned to the second harmonic frequency, it has a high impedance to the fundamental frequency and harmonics other than the second, which is thus selected and applied to the grid of the next multiplier circuit or, if the carrier frequency has been



FREQUENCY DOUBLER CIRCUIT.

FIG. 11.

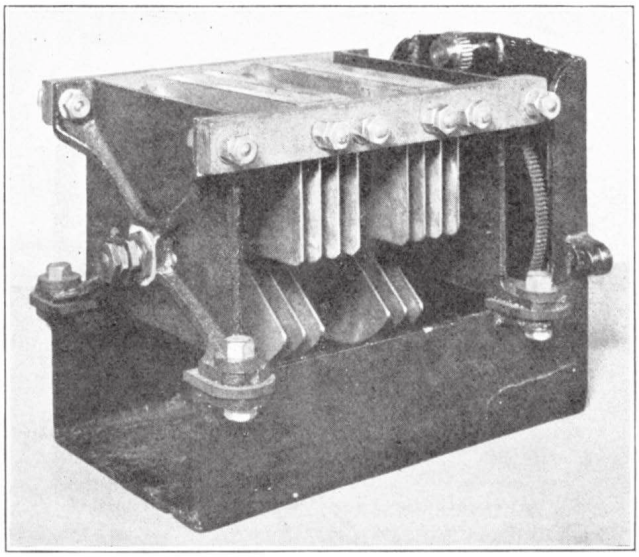


FIG. 12.—ANODE TUNING CONDENSER FOR FREQUENCY DOUBLER STAGES.

reached, to the grid of the first amplifier by means of a coupled circuit. In order to reduce the tendency of this type of doubler circuit to self-oscillate at the anode frequency, both the anode and grid circuits are made highly capacitative. On most short-wave channels it is necessary to use more than one frequency and where possible the frequencies are made multiples of the crystal frequency, so that more than one frequency may be accommodated on one set of multiplier stages simply by short-circuiting one stage. Where intermediate frequencies are necessary, *e.g.*, the Trans-Atlantic channels, where four frequencies of the order of 6,000, 9,000, 12,000 and 18,000 kc/sec are desirable, it is necessary to use more than one set of multiplier stages and switch the outputs to the amplifier stages which are common to all frequencies.

Description of Frequency Multiplier Equipment.—Post Office type valves V.T.45 (50 watt) are used with an anode voltage of 1,500 to 2,000 and grid bias values up to 500 volts negative. In the case of the higher frequencies a V.T.46 (250 watt) is used, as the efficiency of frequency doubling is less and a greater dissipation is therefore required. The circuit components are designed for robustness and minimum maintenance requirements and are arranged in the framework in such a manner as to be as accessible as possible. Fig. **12** illustrates a typical anode tuning condenser in which the supports are cast aluminium, the plates brass and the spindle steel, while high frequency insulation is provided by mycalex bars and D.C. insulation by ebonite bushes. A reduction gear drive is obtained by means of a toothed fibre wheel engaging a brass pinion and insulating the plates of the condenser from the operating knobs.

The lay-out of a bay of frequency control equipment is shown in Fig. **13**. This bay is of the same width as a standard telephone rack and the compartments correspond in depth to panels of standard size. The lowest compartment contains the quartz oscillator oven which rolls into position on wheels and guides. Above the oven is an amplifier stage followed by two doubler stages. At the top right hand side of the rack can be seen the gate switch which disconnects all high tension and grid bias supplies to the equipment when the gate is open.

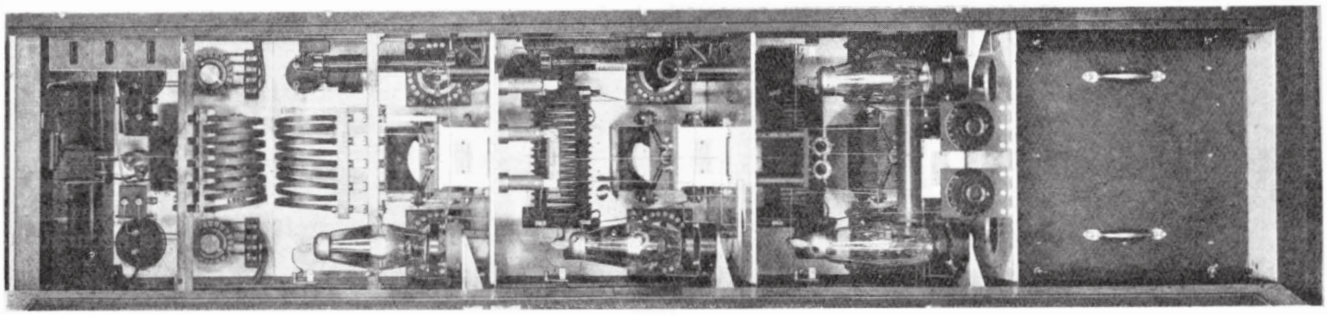


FIG. 13.—SINGLE BAY OF FREQUENCY CONTROL EQUIPMENT.

A complete frequency control equipment usually consists of two bays of oscillator and doubler stages, as shown in Fig. **13**, and a bay devoted to switching, supplies and auxiliary stages. Fig. **14** shows such a bay with supply switches and oven heating transformer in the lowest compartment; above them the rectifier supplying the crystal oscillator supplies and a push-button panel; next a modulation panel; then a panel with valve keying equipment; and, finally, the bridge and switches for the resistance thermometer. A front view of the complete equipment is shown in Fig. **15**. The equipment illustrated was built into a brass framework at the Experimental Laboratories at Dollis Hill and moved *en bloc* to the transmitter site, where it is was joined up to the

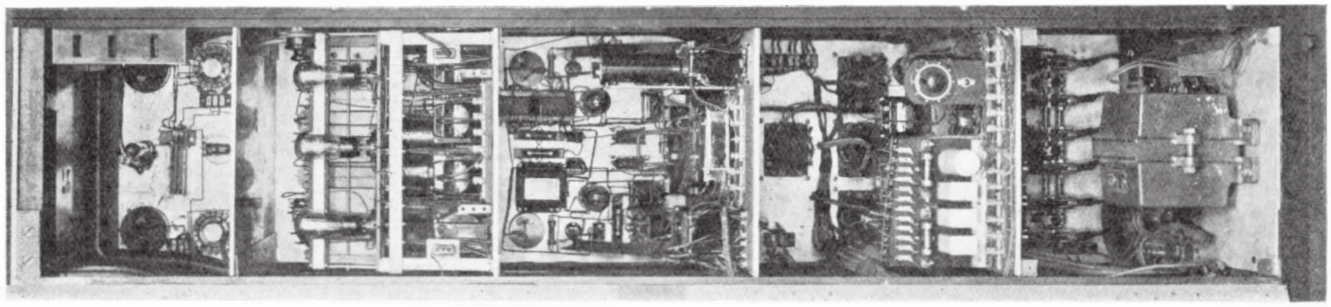


FIG. 14.—AUXILIARY BAY OF FREQUENCY CONTROL EQUIPMENT.

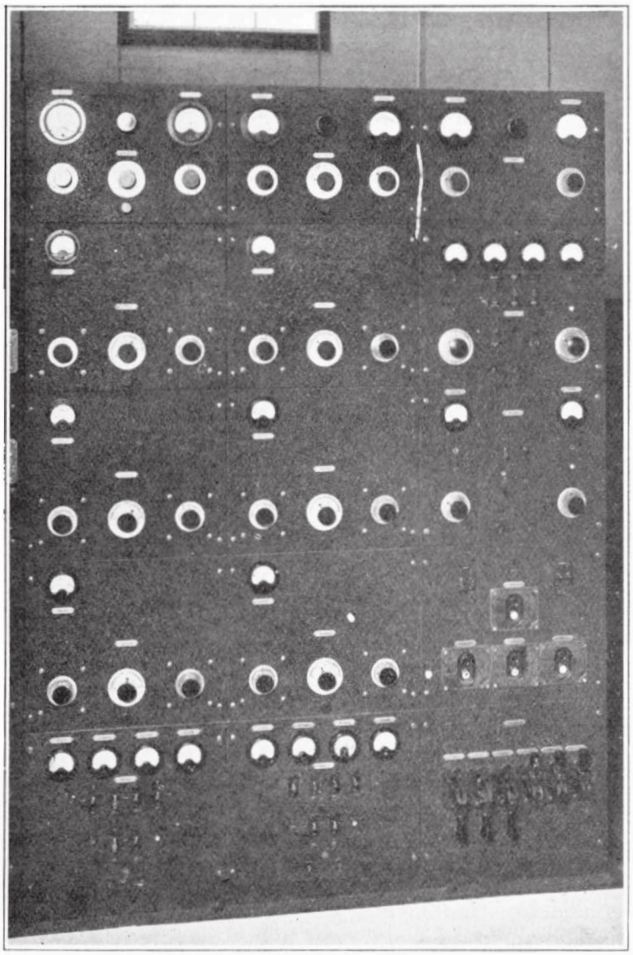


FIG. 15.—FRONT VIEW OF COMPLETE FREQUENCY CONTROL EQUIPMENT.

amplifying stages. The transmitter illustrated is the telegraphy channel GBM at Oxford Radio Station, but the equipment for telephony transmitters at Rugby Radio Station is similar.

Performance Curves.—Curves of frequency taken on two different days during a test run on the 6,985 kc/sec channel of GBM are shown in Fig. **16**. Each curve covers a period of fifteen hours continuous working and both curves refer to the same quartz oscillator. During the intervening day the run was made on the alternative quartz oscillator and gave, on the whole, slightly better results. It will be seen that the maximum deviation from the allocated frequency was 200 cycles/sec and by reference to the lines showing a range of 100 parts in a million about the mean frequency it will be obvious that the performance of the frequency control is well within these limits. The frequency measurements were made at the Post Office measuring station at Colney Heath and are accurate to better than 20 parts in a million.

For the sake of interest Fig. **17** is added. These curves are records of the variation of frequency of the telephony transmitter GBP at Rugby Radio Station, which were taken at Dollis Hill. They were taken for a period of one hour only on three different days and are accurate to five parts in a million. It will be seen that the deviation from the allocated frequency on two days did not exceed 150 cycles, *i.e.*, 14 parts in a million, but that on the third day there was a continual fall from a figure 500 cycles above the correct frequency to the allocation. On enquiry it was found that there had been a power failure at Rugby, that the oven had fallen in temperature by several degrees and that during the hour of measurement it was just regaining its equilibrium temperature. Measurements made over a period of a year on GBP show that the

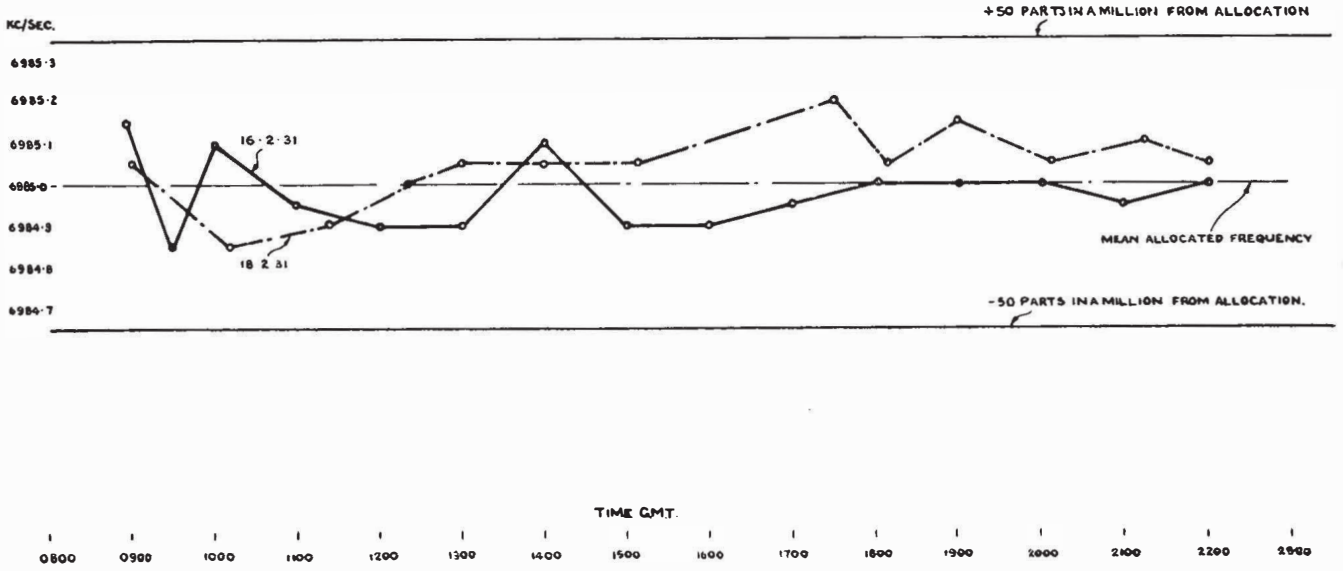


FIG. 16.—FREQUENCY MEASUREMENTS ON GBM. ALLOCATION 6985.0 KC/SEC.

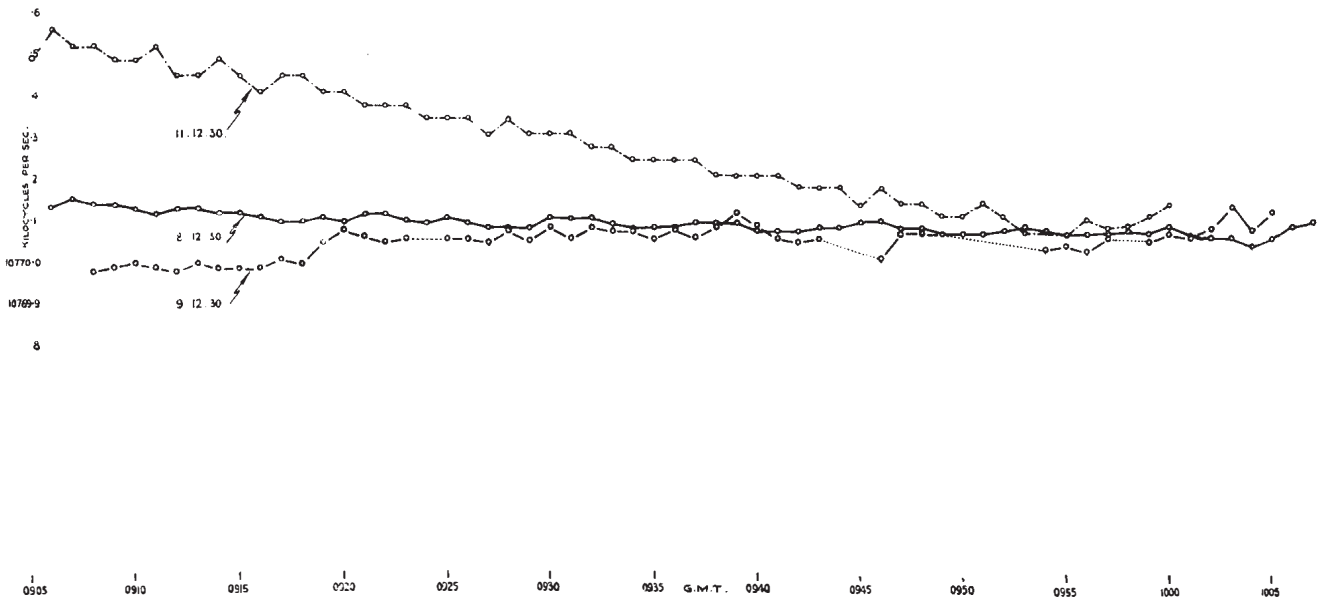


FIG. 17.—FREQUENCY MEASUREMENTS ON GBD. ALLOCATION 10770 KC/SEC.

normal variation is not greater than 50 parts in a million.

Conclusion.—There has been considerable advance in the art of frequency control and frequency measurement during the past five years, and it is now possible to operate short-wave transmitters under commercial conditions with a frequency constancy better than 100 parts in a million.

In anticipation of demands for still further accuracy of frequency control, development will probably proceed on the following lines :—

(*a*) A further reduction in the power taken from the quartz oscillator circuit. A quartz oscillator and buffer amplifier would be designed as a complete unit and treated as a unit source of frequency.

(*b*) A limitation of the range of frequency over which it is possible for the crystal to oscillate by the use of screen grid valves or neutralised circuits.

(*c*) Refinements in the construction of thermostats and ovens.

(*d*) The design of quartz crystal mountings which will compensate for the temperature coefficient of the quartz.

(*e*) Control of the gas pressure in the space around the quartz crystal.

With well-designed apparatus using these refinements it should be possible to produce frequency controls accurate to better than 1 part in a million.

[ERRATUM.—*In the previous article (on p. 161, July Number) the figures for the thickness coefficient should read 2700 and 2000 kc/sec. mm. respectively.*]

PRINCIPLES OF RADIO TOWER DESIGN.

THE "compleat" radio Engineer must indeed be a man of many parts, his knowledge extending from the infinitely small to the stupendously large. From the fascinating study of the behaviour of electrons, he must be prepared to pass on to the consideration of problems relating to electrical mechanical and civil engineering.

All embracing though radio engineering is, there appears to be a tendency in the radio press to devote a disproportionate amount of attention to the physics of the Science to the detriment of the mechanical and civil aspect. And yet, in the design of radio stations whether for "beam" or broadcast working, probably no section offers greater scope for economies than mast design. Within the author's experience, quotations for radio towers from reputable firms vary in the ratio of two to one—this though all forms are quoting to a standard specification in which factors of safety, loading and strut formula are given.

It seems opportune, therefore, to give consideration of some principles of radio tower design. The

first essential is to gain a clear idea of the stresses produced by external loading. To this end, consider Fig. 1.

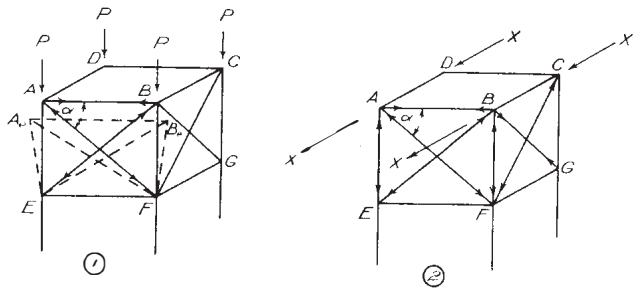


FIG. 1.

Aerial Loading.—The sketches represent the section of a mast having horizontal and double cross bracing. In Fig. 1 (1) vertical loads P due to the superstructure and the mass of the aerials are shown acting along the posts. The usual assumption made is that the posts take the whole of these loads. Actually as the material is not incompressible the section of the posts will be shortened and in consequence stresses will be set up in the bracings. For example, the post sections AE and BF will be compressed to AeE and BeF, thus tending to shorten the cross bracings AF and BE. The resulting stresses produced in the cross bracings give rise to stresses in the horizontal bracings as shown by the arrows.

Flexural Couples.—In Fig. 1 (2) horizontal loads XX set up compressive stresses in the posts AE and BF and tensile stresses in the opposite posts. Here again the assumption is usually made that the bracings AF and BE and the corresponding bracings on the opposite panel are not affected by the shear loads XX. Actually the compressibility of the posts AE and BF causes a shortening of the bracings AF and BE and an extension of the companion bracings in the opposite panel.

Thus in both the cases considered, the bracings take some share of these stresses, usually considered to be taken entirely by the posts.

This fact has given rise to the conception of a "fictitious"* member parallel to the posts which replaces the two cross bracings in the appropriate panels and contributes its quota towards the stresses usually considered to be taken by the posts.

To obtain the constants of this fictitious member consider the point A, Fig. 2 (1) and regard the points E and F as fixed. Let the superstructure above A and B transmit vertical loads P.P. which include the loads in the posts and the vertical components of the loads in the bracing immediately above A and B.

Now according to Castigliano's theorem of least work a structure not initially stressed will store a minimum amount of strain energy under the action of applied external forces.

From this it follows that if W is the total energy in a structure and F is the load in any one member $\frac{\delta W}{\delta F} = 0$. Thus if the members AE, AF and AB have lengths V, D and H, cross sectional areas A_v, A_d and A_h and loads P_v, P_d and P_h respectively, the strain energy in these members

$$= \tfrac{1}{2}\frac{P^2_v V}{A_v E} + \tfrac{1}{2}\frac{P^2_d D}{A_d E} + \tfrac{1}{2}\frac{P^2_h H}{A_h E}$$, where E is Young's modulus.

Again, since A is in equilibrium, the algebraic sum of the vertical forces and of the horizontal forces on A are Zero. Thus, since the diagonal bracing both above and below A gives rise to horizontal loading in AB

$$P + P_v + P_d \sin \alpha = 0$$
$$2 P_d \cos \alpha + P_h = 0$$

Moreover since A and B are similarly loaded, only half the strain energy in AB is associated with A.

$$\therefore \quad W_A = \frac{1}{2E}\left[\frac{(-P - P_d \sin \alpha)^2}{A_v} + \frac{P^2_d D}{A_d} + \tfrac{1}{2}\frac{(-2P_d \cos \alpha)^2 H}{A_h}\right]$$

$$\therefore \quad \frac{\delta W_A}{\delta P} = \frac{1}{2E}\left[\frac{2 \sin \alpha (P + P_d \sin \alpha) V}{A_v} + \frac{2 P_d D}{A_d} + \frac{4 P_d \cos^2 \alpha H}{A_h}\right] = 0$$

$$\therefore \quad -\frac{PV^3}{A_v E V D} = \frac{P_d}{D^2}\left[\frac{V^3}{A_v E} + \frac{D^3}{A_d E} + \frac{2H^3}{A_h E}\right]$$

$$\therefore \quad \frac{P}{\Omega_v V D} = \frac{P_d}{D^2}\left[\frac{1}{\Omega_v} + \frac{1}{\Omega_d} + \frac{2}{\Omega_h}\right] \quad \ldots\ldots\ldots\ldots (i)$$

where Ω_v, Ω_d, Ω_h are the constants $\frac{V^3}{A_v E}$, $\frac{D^3}{A_d E}$ $\frac{H^2}{P_h E}$

Now the load in AE is reduced by $P_d \sin \alpha$ due to the bracings AF and AB, and from (i)

$$P_d \sin \alpha = -\frac{P}{\Omega_v\left[\frac{1}{\Omega_v} + \frac{1}{\Omega_d} + \frac{2}{\Omega_h}\right]} \quad \ldots\ldots\ldots (ii)$$

Thus the load in AE

$$= -P - P_d \sin \alpha = -\frac{P\left[\frac{1}{\Omega_d} + \frac{2}{\Omega_h}\right]}{\frac{1}{\Omega_v} + \frac{1}{\Omega_d} + \frac{2}{\Omega_h}} \quad \ldots\ldots\ldots (iii)$$

Now both AF and BE (Fig. 2 (1)) will contribute in equal measure towards the reduction in loads taken by the posts AE and BF. This reduction is

* *See R.V. Southwell Aeronautical Research Committee. Reports and Memoranda No. 790.*

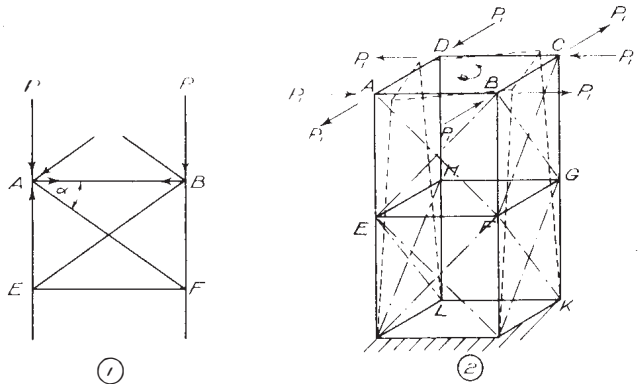


FIG. 2.

Pd. sin α per each post and thus if the two diagonal bracings are regarded as responsible for a single fictitious member having a cross sectional area A_f, the following relationship is obtained :—

$$\frac{A_f}{A_v} = \frac{\Omega_f}{\Omega_v} = \frac{2x \text{ expression (ii)}}{\text{expression (iii)}} = \frac{2\Omega_h\Omega_d}{\Omega_v(\Omega_h + 2\Omega_d)}$$

$$\therefore \Omega_f = \frac{2\Omega_h\Omega_d}{\Omega_h + 2\Omega_d} \text{ where } \Omega_f = \frac{V^3}{A_f E}$$

It follows from this expression that if the horizontal bracing is omitted $\Omega_h = 0$ and therefore $\Omega_f = 0$; in other works the " fictitious " member disappears, thus relieving the cross bracing of stresses due to axial loading and flexure.

Regarded from the physical viewpoint, the removal of the horizontal member AB (Fig. **1** (1)) enables the points A and B to move outward to the positions A_e and B_e when the posts are compressed so that the bracings AF and BE still maintain their original length. Similarly when the stresses in the posts are tensile, the original length s of AF and BE are maintained by the points A and B moving inwards.

In Fig. **3** the value of Ω_f, for the fictitious member has been plotted in terms of Ω_d for various values of the ratio $\frac{\Omega_h}{\Omega_d}$

It has already been shown when $\Omega_h = 0$ $\Omega_f = 0$. When $\frac{\Omega_h}{\Omega_d} = \infty$; $\Omega_f = 2\Omega_d$, but as Ω_d now approximates to Zero, the fictitious member again does not operate when the diagonal bracing is non-existant. However, under certain conditions the value of Ω_f might be considerable, as for example when $\Omega_h = \Omega_d$. In this case $\Omega_f = \frac{2}{3}\Omega_d$, and the " fictitious " member takes an appreciable load.

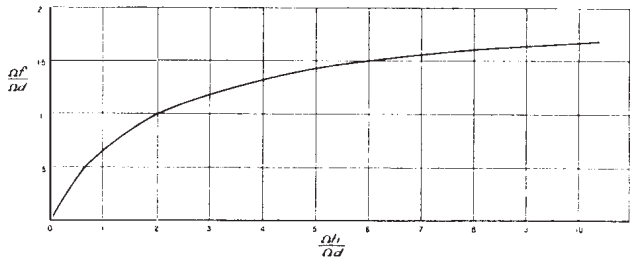


FIG. 3.

It is thus obvious that to ignore the " fictitious " member might result in too much metal being used on the posts and too little in the bracings. This probability leads to the belief that main horizontal bracings can usually be omitted with advantage from radio towers, since their omission enables a readier and more exact computation of the stresses to be made.

Furthermore the elimination of the horizontal face bracing may result in a more economical structure.

Consider Fig. **4** which represents a panel of a tower built of square angle mild steel. The diagonal bracings are regarded as tension members and thus only one of these members can be considered as resisting shear. The loading and stresses in the various members of the panel are shown in Table 1 below.

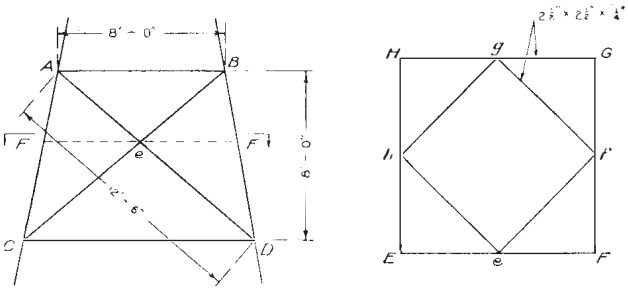


FIG. 4.

TABLE 1.

Member.	Dimensions of angle. Length. Ft.	Dimensions of angle. Size of flanges inches.	Load lbs.	Actual Stress lbs. sq. in. c = compressive e = tensile	Permissible Stress $18000 - \frac{80l}{r}$ for compressive members. lbs. sq. in.
BD	8	6 × 6 × ¾	98900	11700 c	11500
BC	12.5	3 × 3 × ⅜	29600	14000 e	17000 on net section, *i.e.*, 14800 on full Section Allowing for bolt holes).
AB	8.0	4 × 4 × [illegible]	18900	8050 c	8250

If the diagonal bracings had been designed as struts and the small supporting angles Ee Ff Gg Hh had been inserted instead of the horizontal bracing AB, etc., both diagonals would have been effective bracings and the stresses would have been as shown in Table 2.

and the force in the bracing $= \frac{T.AF}{4AB^2}$. This result is the same as that obtained from Batho's theory which states that the shear perpendicular to the plane of two parallel trusses is equal to the torque

TABLE 2.

Member.	Dimensions of angle. Length. Ft.	Dimensions of angle. Size of flanfies inches.	Load lbs.	Actual Stress lbs. sq. in.	Permissible Stress $18000 - \frac{80l}{r}$ for compressive members. lbs. sq. in.
BF	4.0	$5 \times 5 \times \frac{3}{4}$	98900	14250	14000
FD	4.0	$5 \times 5 \times \frac{3}{4}$	98900	14250	14000
Be	6.25	$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{4}$	14800	8750	9170
CC	6.25	$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{4}$	14800	8750	9170

Thus in the case considered a saving in metal of about 18% and a reduction in exposed wind surface of 7.5% is made by eliminating the main horizontal bracing. This double reduction affects the size of the section of the posts and bracings required in the lower portion of the structure very appreciably.

In addition to the horizontal shearing loads due to aerial pull and wind which produce a flexural couple increasing in value with distance from the top of the structure, towers supporting curtains of wires on cross arms might be subjected to appreciable uniform flexural couple. For example, should one of the two steel cables which support the exciter and reflector curtain respectively, fail, there will be a uniform bending moment equal to WD where W is the vertical component of the tension in the remaining cable, and D the horizontal distance of the cable from the centre line of the tones.

Torsion.—Moreover the horizontal component will set up a uniform torsional couple to resist which provision must be made. Consider a torsional couple (Fig. **2** (2)) applied to the top of a structure which is fixed at the base. It is evident that this structure, if diagonal face bracings are absent, will present little resistance to torque, nor will the addition of any other horizontal bracing such as E F G H have any appreciable effect.

If however diagonal face bracings are added as shown by the Chain lines, the torque is opposed by compressive stresses induced in members such as AF, FK and tensile stresses in other members such as BE, EL.

The torque applied to the top of the mast can be substituted by forces P_1 applied at the posts. In each panel round the mast, bracing such as AF will have compressive forces induced in them equal to $P_1 \frac{AF}{AB}$ whilst bracings similar to BE will have tensile forces numerically equal to the compressive forces. Since AB = BC, the torque $T = 4 P_1 AB$ multiplied by the distance between the trusses divided by twice the area of the trusses : or

$$\text{Shear} = \frac{T.AE}{2AB^2}$$

Since two diagonal bracings resist this shear, the forces induced compressive in one case, tensile in the other—

$$\text{equal } \frac{T.AE}{2.AB^2} \times \frac{AF}{2AE} = \frac{T.AF}{4AB^2}$$

The various types of loading which a radio tower is required to resist have now been described. It must not be assumed, however, that all are applied simultaneously. For example, in the case of towers supporting a beam array maximum torque and uniform flexural couple occur when the cable supporting one curtain fails, but in this condition neither the variable flexural couple nor the axial loading are a maximum. The design must provide for the worst combination of loading likely to occur simultaneously.

Columns.—An accurate strut formula applicable to all conditions obtaining in tower structures, is not realizable. The posts and bracings, between unsupported lengths, form a series of struts with varying and unascertainable degrees of fixation. It is common practice to regard the struts as pin jointed, the deflection curve of posts being regarded as shown exaggerated in Fig. **5** (1). It is, however, obvious that the type of bracing joint will influence the degree of fixation and the extent of the free length of strut. When a single bolt or rivet is used, it is logical to regard the slope as a maximum at the joint. Such, however, is not the case when a stiff plate joint is used (Fig. **5** (2)) and the designer is therefore justified in regarding the length of the strut as varying between the actual length and $\frac{2}{3}$ the length, according to the type of joint. With regard to a suitable strut formula, within working limits

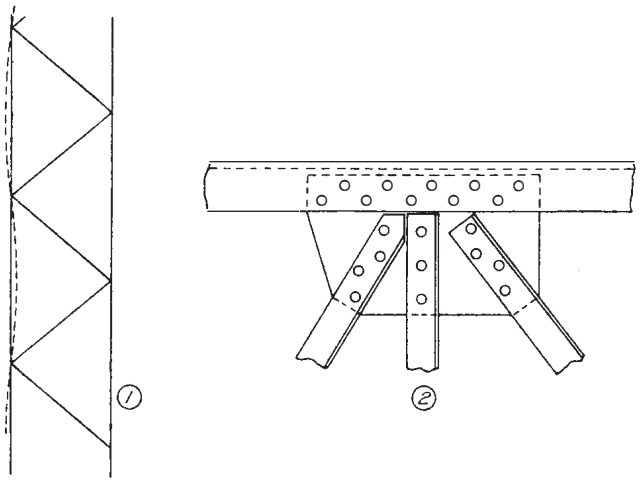


FIG. 5.

of stress a straight line formula of the form $f_s = f_0 - \frac{kl}{r}$ is probably as accurate as any of the numerous formulæ suggested by various authorities. The experimental investigations of Robertson* have shown that, in general, for mild steel struts having free ends, Euler's formula is correct within the limits of proportionality and that Southwell's modification for variation in the value of Young's Modulus of Elasticity gives accurate results up to the yield point. These results, however, are contingent upon ideal conditions. The strut must be straight and non-eccentrically loaded, conditions never realized in practice. Robertson further shows that the many published results of tests on practical struts, having fixed or flat ends, the critical loads lie within an area enclosed by the yield line, the Euler curve and the Perry curve, the latter having a simplified coefficient to account for probable initial curvature eccentricity and variation of Young's modulus. The area is, in most cases considerable and illustrates the difficulty of obtaining reliability. It is this lack of certainty that causes designers to prefer the simple straight line formula, the accuracy of which within the limits of $\frac{l}{r} = 50$ to 160 is not unreasonable, where l is the effective length of strut and r is the minimum radius of gyration. For mild steel angles, a suitable formula for struts is $f_s = 18.000 - \frac{80l}{r}$ where f_s is the permissible stress.

Wind Loading.—Except with small towers the effects of horizontal loading due to wind, usually predominate over all other loading. This being so, it is surprising how little has been published upon investigation into the question of wind resistance of various sections and types of lattice structures.

* *"The Strength of Struts," selected Engineering Papers, No. 28, Inst. Civil Eng.*

Various cross sections of post have been proposed and employed for the purpose of reducing the ratio of greatest to least radius of gyration, but little attention has been given to the equally important question of wind resistance of the member. The assumption generally made is that the resistance to wind is equal to the product of the Area of the Section, projected on a vertical plane, and the horizontal wind pressure on a plane surface per unit area normal to the direction of the wind. In other words all types of section having the same projected area on a vertical plane of reference, are regarded as offering the same wind resistance. Such an assumption is obviously wrong. The shape of Cross Section, the aspect ratio, the angles of incidence of the wind, the degree of screening, all effect the problem. The most reliable method of arriving at the wind loading is to build a model and test in a wind tunnel. The model should be rotated about a vertical axis to ascertain how the wind resistance varies as the angle of incidence is changed. It has been ascertained that for objects geometrically similar the scale effect on wind resistance has little importance. Thus results obtained from a model can be applied to the full sized structure. Failing a model a reasonably accurate computation of the wind resistance can be made by testing a few lengths of post and bracing. The sections tested should be geometrically similar, but need not be the same size as the working members. Tests on several lengths are necessary to obtain a curve of the force coefficient for varying aspect ratio, *i.e.*, ratio of length to breadth. The necessity for this precaution will be realized from an inspection of Fig. **6** which gives the force coefficient K_f or a V angle iron in the expression $R = KAV^2$

where R = the wind resistance in lbs.

A = area of one flange of the angle in sq. ft.

V = velocity of wind in miles per hour.

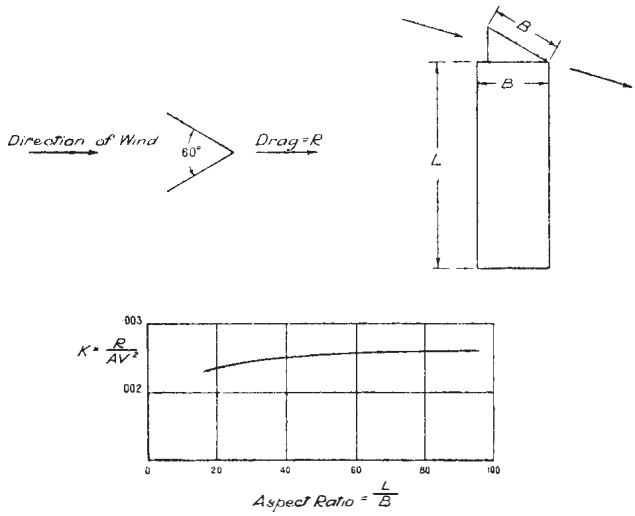


FIG. **6**.

As the corner posts of towers are nearly vertical it is sufficiently accurate to rotate the post section about the longitudinal axis normal to the wind. The bracing however should be tested in such a manner as to simulate actual conditions, and should therefore be rotated about an axis making appropriate angles with the longitudinal axis of the member. To illustrate the variation in the value of K for different angles of incidence of the wind, a typical curve is given in Fig. **7** for a V section having equal flanges. Fortunately the large variations in the value of K for individual members is usually nullified in practice due to the fact that the various members present different fronts to the wind. For example, a square tower presents four faces to the wind, each face making $\pm$ 90° with its neighbour. Thus there is an averaging effect. In the case of a square tower, a good average value for K is 0.0035.

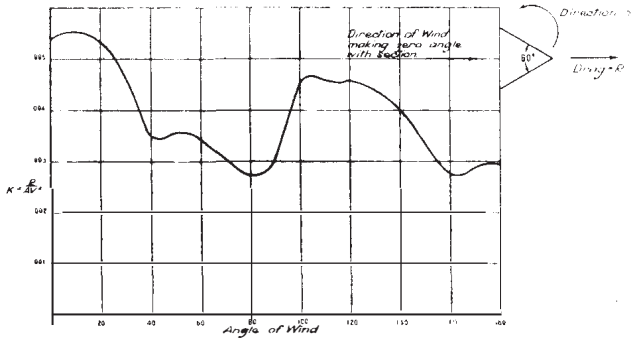


FIG. 7.

A considerable degree of uncertainty exists as to what wind pressure per square foot of surface should be taken. Opinions differ widely; for example, some firms of repute specializing in steel towers, allow 25 lbs. per square foot of surface uniformly distributed over one and a half times the normal projected area of the tower. This forms a marked contrast to the values taken in the design of the Rugby 820 ft. masts, viz., 60 lbs. per square foot over 1.8 times the projected area of one face. This high value was taken owing to the meagre information available when the masts were designed of the wind velocity at considerable heights above ground. The ratio of total loading in these two cases is thus 1 :2.9. In America wind pressures are taken at a much less value than in England. The Californian Railway Commission, for example, allow—or used to allow within recent years—13 lbs. per square foot of projected area on both sides of the tower. It is therefore interesting to examine some recent figures of wind velocities and from these to calculate possible values of wind load when a typical structure. The maximum wind velocities which, according to the meteorological office, have been recorded in the British Isles are shown in the Table below.

Place.	Year.	Highest Gust on record Miles per hour.	Height of aerometer above ground.
Pendennis (Cornwall) ...	1905	103	65
Quilty (Clare, Ireland)	1920	110	40
Scilly	1922	108	32

In the gales during the end of 1929, a wind velocity of 110 miles per hour was recorded in S.W. England.

The first point of interest is that the above pressures were recorded at heights not far removed from the ground. At higher elevations it is safe to assume that the velocities were higher. Taking 110 miles per hour for the wind velocity and 0.0035 for the value of K for square, equal angle towers, the wind resistance will have a value of 42 lbs. per square foot. A safe maximum value would therefore appear to be 45 lbs. per square foot. However, since gusts of even 90 miles per hour are not often experienced in the British Isles, it may be economically sound in some cases to design smaller towers up to about 120 feet for wind pressures of 30 lbs. per square foot; the type of service, the location and the economics of the question decide the exact values.

Screening.—In the foregoing discussion upon wind resistance no allowance has been made for screening.

With ordinary lattice towers where the ratio of distance apart of posts and face bracing to the width of flange is considerable, the allowance to be made for screening effects is not great. Stanton, in some of his early experiments,* showed that the total loading upon two similar parallel lattice plate frames varied from 1.6 to 1.78 times the load upon the windward plate when the ratio of distance apart to the width of the plates increased from 16 to 70. Thus within wide limits of variation of the ratio, the screening coefficient does not vary greatly and converges towards 1.8 for great values of the ratio. It is the practice in the British Post Office Engineering Department to use a maximum value of 1.8 for tower design. It is, however, evident that the value of the coefficient will change appreciably in an ordinary tapered self supporting tower, usually increasing towards the ground end of the structure. In a detailed design allowance should be made for this variation.

Particularly at the top of a tower should advantage be taken of the reduced value of the screening factor in order to start the design of the top panels with as small sections as practicable. Each increment of top horizontal loading, whether due to wind load or to aerial pull, necessitates additional increments of section throughout the tower.

There is an economical limit to the dip permissible with every aerial supporting cable. The

* *Proc. Inst. Civil Eng., 1904, Vol. CLVI.*

weight of a tower increases considerably with top pull and it is thus frequently more economical to erect a higher tower to allow an increased dip, since the resulting reduction in top pull enables lighter steel sections to be used.

T.W.

TRANSMISSIONS OF WIRELESS WAVES OF STANDARD FREQUENCIES FROM THE NATIONAL PHYSICAL LABORATORY.

(STATION CALL SIGN G.5 H.W.)

IN connection with the work of the Radio Research Board of the Department of Scientific and Industrial Research, waves of accurately known frequency have been transmitted for some years past from the Wireless Station at the National Physical Laboratory for checking the calibration of wave meters and other apparatus.

Up to this year the frequencies employed have been suitable for commercial purposes, but commencing on 3rd March last, at the request of the Post Office, arrangements have been made for a standard frequency transmission to be sent out which enables owners of Amateur Experimental transmitting stations to enjoy the same facilities. This standard frequency transmission is made on a frequency of 1785 kilocycles per second (*i.e.*, 168.6 metres), and is transmitted on the first Tuesday in March, June, September and December, commencing at 9 p.m. G.M.T. The standard transmission is preceded by the announcement C.Q. de G.5 H.W. repeated several times followed by standard wave transmission on 1785 kilocycles. The announcement is followed by a continuous dash, the whole lasting 10 minutes. This procedure is repeated six times, *i.e.*, at 2100 (9 p.m.) 2110, 2120, 2130, 2140 and 2150.

By the use of this standard frequency transmission a very accurate calibration of wavemeters or transmitters can be made although, as is the case in all accurate measurements, a certain degree of skill is required. The method detailed below is that suggested by the Post Office for utilising this standard frequency transmission to obtain the greatest accuracy with the apparatus usually available at amateur transmitting stations.

The apparatus required to check a crystal controlled transmitter or to calibrate a crystal wavemeter by means of this transmission, is, firstly, a receiver, the settings of which can be accurately determined, having a range from 1785 kilocycles to the highest calibration frequency required, secondly, a calibrated oscillator having a range of 200 to 1785 kilocycles. If the receiver is not of the self oscillating type it will be necessary to employ a separate hetrodyne in conjunction with it.

Dealing first with the case of a crystal controlled transmitter working in the 42 metre band and which utilises a wavemeter of the absorption or resonance type. The receiver is first set to the silent point of the standard frequency transmission, that is, to 1785 kilocycles.

The output from the oscillator is then closely coupled to the receiver (which is assumed to self oscillate), care being taken to ensure that there is no frequency interaction between the receiver and oscillator. The oscillator is then set to oscillate on 1785 kilocycles by varying its frequency until the silent point of its oscillation is obtained on the same setting of the receiver as that obtained for the silent point of the standard wave transmission. Leaving the oscillator unchanged, the receiver is next tuned to the 4th harmonic of the oscillator, that is, 7140 kilocycles per second, or the mid point of the 42 metre band.

The oscillator is then stopped and the transmitter made to self oscillate and its frequency adjusted to the same setting as the receiver, that is 7140 kilocycles per second. The wavemeter setting for this frequency is then obtained by measuring the transmitter frequency in the normal way. It is desirable that this setting should correspond with the middle of the wavemeter scale.

To obtain a calibration curve of the wavemeter on this band points are required separated by a smaller frequency interval than 1785 kilocycles from the mid point calibration already obtained, a separation which would be obtained by taking the 5th and 3rd harmonics of the previous oscillator settings.

To obtain two further points which will be less widely separated, the receiver is set to the silent point of the calibrated wave transmission and the oscillator frequency is decreased until its 5th harmonic corresponds with this setting of the receiver that is 1785 kilocycles. The fundamental of the oscillator will therefore be 357 kilocycles per second. The receiver is retuned to the setting previously obtained for 7140 kilocycles and the 20th harmonic of the oscillator will then be heard on this setting. The tuning of the receiver is then slowly varied until the 21st harmonic of the oscillator is heard, that is 7497 kilocycles per second. The transmitter is then tuned to oscillate on this frequency and the wave-

meter reading again obtained. In a similar way the 19th harmonic of the oscillator may be tuned in and the process repeated giving a third point on the wavemeter at 6783 kilocycles per second.

To obtain accurate measurements the wavemeter range should be such that the three calibration frequencies are respectively near the minimum mid-point and maximum of the scale.

Even greater accuracy may be obtained by utilizing the 6th or 7th harmonic of the oscillator in place of or in addition to the 4th, thus obtaining check points with less separation.

A similar procedure is adopted to obtain checks on the 20, 10 and 5 metre bands, as it will be found that the mid points of these bands correspond with a harmonic frequency of 1785 kilocycles per second. It is not, however, necessary to employ such a high order harmonic of the oscillator for obtaining check points and harmonics should be selected to suit the range of the wavemeter used.

For example, in the 5 metre band it may be found satisfactory to set the oscillator to 3570 kilocycles per second, and to utilise the 15th, 16th and 17th harmonics corresponding to frequencies of 53550, 57120 and 60690 kilocycles per second.

To calibrate a non-crystal controlled transmitter, which in consequence uses a crystal controlled wavemeter under the regulations relating to amateur transmitters, the procedure is similar to that already described except that the transmitter is calibrated instead of the heterodyne wavemeter, and this calibration is used to check the crystal wavemeter.

NOTES & COMMENTS

THE LATE DR. HANSFORD.

THE many friends of the late Dr. Hansford will be glad to learn that the education of his two sons, as he had intended, is now assured. The elder son has been awarded a Scholarship at Shrewsbury School with a grant of £140 p.a. and enters the School immediately. The younger son was admitted last January to Christ's Hospital in recognition of his father's public service.

The two sons are happily endowed with many of their father's qualities and their careers will be watched with kindly interest.

A NOVEL APPLICATION OF THE PHOTO-ELECTRIC CELL.

A description of some recent developments, involving the novel application of at least three modern pieces of apparatus, may be of interest.

One type of recorder used by the Department for trunking investigations consists of 20 pens which draw 20 lines on a paper ribbon or chart. When the pens are operated, the lines drawn move away from the zero position by about one eighth of an inch and remain off normal until the pen is released. The analysis of these records, involving the accurate determination of the total time the pen has been operated, and the number of times, is very tedious, and experiments are being made with a view to avoiding this monotonous work which has hitherto been done by human effort.

The instrument involves the use of a photo-electric cell, a valve amplifier, and a modern A.C. synchronous clock. The chart with the pen records on it is drawn forward so that any one of the 20 lines passes under a powerful source of light focussed to a point on the line. The light passed through the paper is collected by a photo-electric cell. Obviously when the line moves off normal, *i.e.*, out of the light, the paper will pass more light to the cell as there is now no ink line in the way. The cell therefore will give an increased electrical output. If the light to the cell is rapidly interrupted by means of a shutter, the output will rise and fall rapidly and may then be dealt with by a valve amplifier, which, of course, is useless for amplifying D.C. variations. Any increase of light to the cell (caused by an off normal portion of the line) causes the average value of the cell output to increase. This in turn will cause the amplifier output to rise sufficiently to operate a relay in the circuit. The relay closes two local contacts, one to operate a meter of the Veeder type and the other to close the circuit of an A.C. synchronous clock. These clocks work off 50 cycle A.C. and have a very small starting lag. The meter will show the number of calls and the clock will show the actual total time the pen has been operated provided the original and analysis speed of the chart are known.

THE FARADAY CENTENARY EXHIBITION.

The above exhibition in the Albert Hall, London, was opened on the 22nd ult. and continues till the 3rd October. Organised jointly by the I.E.E. and the Royal Institution, the floor space is divided into five sections, one of which, dealing with Electrical Communications, was arranged by the P.O. Engineering Department. Valuable assistance and co-operation was freely given by the Telephone Development Association, the Cable Manufacturers' Association, the Accumulator Makers' Association, the Radio Manufacturers' Association, the B.B.C., the Science Museum and the Imperial and International Communications, Ltd. Part of the space allocated was taken up by the Institution of Radiology.

The lay-out was divided into the following groups, arranged radially outwards from the Royal Institution stands which surrounded a statue of Faraday in the centre of the hall. On the R.I. stands fundamental experimental work was being shown to link up the original with the later developments of the art.

(1) Early telegraph apparatus and plant.
(2) Telegraph Land Line operation.
(3) Telegraph Submarine Cable operation.
(4) Early telephone apparatus and plant.
(5) Modern telephone equipment in operation. Manual and Automatic.
(6) Telephone Repeaters, Carrier Telephony.
(7) Underground and Submarine Cable.
(8) Early Radio apparatus and equipment.
(9) Modern Radio: Telegraph and Telephone, Commercial.
(10) Modern Radio Broadcasting.

The early specimens were drawn mainly from the Science Museum, South Kensington, which holds an unique assembly of telegraph, telephone and radio apparatus. The A.T.M. Co. showed a model of the Director system in operation, Ericssons' a Manual exchange with an R.A.X. satellite from the G.E.C. Messrs. Creed had two Teleprinters No. 7A (column printers) in operation side by side with P.O. Wheatstone sets, while the I. and I. Communications showed two terminal submarine stations working through a regenerative repeater. Marconi's lent a valuable display of early and modern radio material, and the B.B.C. installed the six units which will, later in the year, form the Scottish Regional Transmitter. The S.T. & C., Pirelli-General, the B.I. and Henleys sent samples of typical telephone cables and Thos. Bolton & Sons specimens of line wires, etc. Siemens Bros. showed a very fine exhibit of submarine cables, telegraph and telephone, loaded and unloaded. The P.O. Radio Section exhibited a 500 kW thermionic valve made by Met-Vickers, a model short-wave aerial array, a long and a short-wave receiver, and with the aid of the S.T. and C. Co. illustrated "speech inversion" on the T.A.T. The Research Section demonstrated the effects of distortion on speech and music. The Accumulator Makers' Association installed a 50 v 300 Ah battery which supplied current to the exchanges and for sundry other purposes.

AUSTRALIAN TRANSCONTINENTAL TELEPHONE CIRCUIT.

The first commercial telephone circuit connecting Western Australia with the eastern portion of the continent was completed recently. Australian settlement may be divided into two distinct groups, one on the West coast and the other on the East, with a large tract of practically uninhabited country in between. Prior to the completion of the telephone channel, rapid communication between the groups was supplied by telegraph circuits which have existed for many years.

The total length of the new circuit which runs from Adelaide to Perth, is 1600 miles, in which length there are seven intermediate voice frequency repeater stations. Between Port Augusta on the edge of the eastern settlement, and Kalgoorlie, the outpost of the western settlement, the circuit follows the Transcontinental railway.

An eight channel carrier telegraph system is superimposed on the telephone circuit and carrier repeaters are installed at the same stations as the voice frequency repeaters. The carrier telegraph apparatus and the voice frequency repeaters were supplied by Standard Telephones and Cables, Ltd., the equipment being manufactured in England.

Since the opening of the new circuit, it has been extended gradually to all the Eastern States, the final extension being to Queensland on 25/5/31. The route distance between Brisbane (the capital of Queensland) and Perth is 3400 miles, but commercial calls have been completed between Townsville and Perth—a circuit length of 4200 miles.

The present daily calling rate between the Eastern and Western States is approximately 20. The charge for a three minute conversation between Adelaide and Perth varies from 12/- to 6/-, depending upon the time of the day the call is made, whilst the maximum and minimum rates for Brisbane-Perth connection are 18/- and 9/- respectively. The main source of revenue on the route is of course from telegraph traffic.

R.B.

COMMUNICATION ENGINEERING IN AUSTRALIA.

In the Journal of the Institution of Engineers, Australia, Vol. 3, No. 2, February, 1931, Mr. J. M. Crawford, Engineer-in-Chief of the Australian Commonwealth Posts and Telegraphs, who was at one time Secretary of the I.P.O.E.E., contributes a paper under the above heading, which was read before the Engineering Conference, Melbourne, March, 1931. The paper describes the scope of the work of the Communication Engineer, with particular reference to the telegraphic and telephonic problems which have to be overcome in Australia. The organisation and research facilities of the P.M.G's Department are outlined, and conclusions as to the possible lines of future development are given.

A TELEPHONE DICTIONARY IN SEVEN LANGUAGES.

We have received from M. Dayat, Chef du Service Commercial de la Librairie de l'Enseignment Technique, 3 Rue Thénard, Paris (5e), a copy of "Vocabulaire Téléphonique International" in seven languages. This valuable publication is a product of the Consultative International Committee (the C.C.I.) for Telephone Communication over Long Distances, which set up a special commission for the purpose of preparing a technical dictionary of telephone terms and definitions. The Commission has completed its work, which has been checked by the Telephone Administrations of Germany, Spain, France, Great Britain, Italy, Sweden and the Union of R.S.S., and this volume of 386 pages (229 pages of telephone

vocabulary and 157 pages of alphabetical index) is the result.

The dictionary is published by Librarie de l'Enseignment Technique and copies can be obtained by remitting 100 francs, plus 9 fr. 40 postage for countries outside France, to M. le Directeur de la Librairie at the above address, 3, Rue Thénard, Paris (5e).

2nd September, 1931.

The Managing Editor,
P.O.E.E. Journal.

Sir,

MECHANISED SIGNAL WAGONS.

Your last issue contained a sketch of a telegraph wagon used in the Crimea, 1854, also a plough for laying covered cable.

MECHANISED SIGNAL WAGON.

The attached photograph may be of interest to your readers as it shows the latest development in cable laying from a mechanised cable wagon manned by representatives of the G.P.O. and of Messrs. Siemens Brothers, of Woolwich.

Yours truly,

"SIGNALS."

THE GRUB MENACE.

The Managing Editor,
P.O.E.E. Journal,
Engineer-in-Chief's Office,
Alder House,
London, E.C.1.

General Post Office,
Suva, Fiji Colony.
11th August, 1931.

Sir,

I have the honour to refer to an article, "The Grub Menace," which appeared in your July issue and related to an attack on the jumper wires by a type of clothes moth at the Tandem Exchange.

It may be of interest to those concerned to know that a similar serious onslaught was made on the jumper wires on both the main and intermediate frames of the Suva Exchange during December, 1930. The attack in many instances was so severe that only the enamelling was left untouched, the complete covering of the wires having been eaten away. A noticeable feature was that all waxed wires were left untouched, only wires which had not been waxed being attacked. A specimen piece of wire is enclosed.

The assistance of the Department of Agriculture was obtained and a copy of the report by Mr. H R. Surridge, A.R.C.Sc., is enclosed. In order to carry out the fumigation proposed by the Department of Agriculture a wooden case was built round the intermediate frame—the main frame having previously been cased in glass to withstand climatic conditions. The fumigation process described by Mr. Surridge proved entirely satisfactory and there has been no recurrence of the trouble.

In order to gauge the quantity of fumigant used it may be stated that the Suva Exchange is a magneto multiple of 600 lines with one trunk panel.

I have the honour to be, Sir,
Your obedient Servant,
P. D. BERGO,
Postmaster-General.

MR. SURRIDGE'S REPORT.

From the Agronomist, Coconut Committee.
To the Director of Agriculture, Suva, Fiji Colony.
Subject: Anthremus vorax attacking insulations at the Telephone Exchange, Suva. 28th January, 1931.

1. It was reported to you that the insulation of certain important telephone wires at the Suva Exchange was being destroyed by a small grub and beetle, and advice and assistance asked for its destruction and control. At the request of Mr. Taylor, Entomologist, I accompanied him for the purpose of examining the damage reported and giving what assistance was possible.

2. The insulation of the cables was untouched, and the insulated wires that were covered with paraffin wax were also untouched, whereas those wires covered with a dry insulator, that is, one without wax, were found to have the cotton, etc., destroyed, thus leaving the wires exposed with the possibility of creating innumerable short circuits.

3. After a thorough examination of the damage and of those other wires and cables within the Exchange, it was recommended to the Postmaster-General that the Exchange should be closed down at a convenient time to allow for the building to be thoroughly fumigated with cyanide gas for a period of twelve hours.

4. After due consideration by the Postmaster-General he decided against this type of fumigation on the grounds of possible damage by corrosion to

some of the most delicate parts of the metal mechanism in the Exchange. Reference to the Government Chemist on this matter failed to reassure the Postmaster-General, with the result that other possible means of control had to be explored.

5. Mr. Taylor, on reference to various authorities, noted that most fumigants suggested would probably attack metal to a greater degree than H.C.N. except in the case of Tetrachlorethane. This substance is not freely obtainable at present in this Colony, so that Paradichlorbenzene was suggested.

6. The Government Chemist confirmed the statement that the use of this substance as a fumigant would be harmless to the mechanism and also to human beings in the strength used.

7. In the meantime a wooden cabinet had been fitted around the damaged wires and thus ensured that fumigation with paradichlorbenzene could be carried out under control during normal working hours without danger to human beings or the telephone mechanism.

8. At this stage of the investigation Mr. Taylor had to proceed to SavuSavu, so that in his absence I carried on.

9. On Wednesday, 21st January, I supplied Mr. Alcock, in charge of the Telephone Exchange, with three cigarette tins holding half a pound each, six test tubes ($6'' \times \frac{3}{4}''$) and six test tubes ($5'' \times \frac{1}{2}''$) which absorbed another half pound between them, with instructions to place in the enclosed wooden cabinet, one cigarette tin and the six large test tubes, placing the tin on a shelf and suspending the test tubes from the cables above the wired terminals. The remainder of tins and tubes to be placed in similar positions in the larger cabinet fitted with glass doors.

10. These instructions were carried out by 4.0 p.m. that day. At 9.0 a.m. on Thursday, 22nd January, the wooden cabinet was examined when it was noted that the presence of the fumigant was objectionable, but at that concentration not effective.

11. Some small boards were obtained and one pound of the paradichlorbenzene spread out on them and placed just above the infected wires in this cabinet, the doors replaced and all cracks and holes plugged with cotton wool. This was completed by 4.0 p.m. on the 22nd and no examination made until 8.0 p.m. on the 23rd, when it was discovered that many of the larvæ were lying on the floor of this cabinet, apparently dead. As this cabinet was not required for working operations, it was resealed and left until January 27th when it was duly opened, and some of the bodies of the larvæ collected, placed in a test tube and sent to this Office for further examination. The reason for this is that it is stated that such larvæ can live for considerable periods without air. It is necessary therefore to know whether they were killed by the gas, or were just in a resting stage.

12. This fact stands out that paradichlorbenzene if it does not destroy the larvæ or beetle at least acts as a deterrent, and it is recommended that some should always be kept in these cabinets as a preventative. Also that in future, all wires should be waxed, since it was found that waxed wires were not attacked.

13. The beetle has been identified by Mr. Taylor as possibly Anthremus vorax, pending confirmation of specimens forwarded to the British Museum for identification.

(Sgd.) H. R. SURRIDGE,
Agronomist, Coconut Committee.

THE GROWTH OF A LEGEND.

Summer Heath,
Hutton,
Nr. Preston.
5th September, 1931.

The Editor,
P.O.E.E. Journal.

Dear Sir,

Although relegated to the herbaceous border for the last five years, I still look with interest for the quarterly record of Telegraph and Telephone matters contained in " our " Journal, and it was with some amusement that I saw that the " rat " story was again to the fore. This process of threading a duct has ever been like the performance of the Indian juggler and the disappearing boy, nobody has actually seen it done, but lots of people know somebody who was told of it by someone whose veracity is unimpeachable.

Now it is really time that that rat was led out of the duct.

Mr. Stubbs has given the official version of an occurrence in the London District of about fifty years ago. A slightly different account was current among the " Works Order " and " Maintenance " men of the period.

This was before the time even of " G.P. quad " cables, single G.P. covered wires only being used. The method of drawing in additional wires was to cut one of the existing wires, and use it to draw a sash line into the pipe. The wire thus drawn out was included with the new ones, and all drawn in by means of the sash line. It sometimes happened where wires were few, and an easy " pull " was anticipated, that time was saved by using the existing wires to draw in the full complement of wires required. This method was not officially recognised, for obvious reasons, and it happened on one occasion (probably that referred to by Mr. Stubbs) that unexpected difficulty caused the two groups of wires to part company in the pipe. The foreman got a well deserved " telling off " from his Inspector, with dire threats of what would happen if the wires were not restored early.

When the Inspector arrived on the spot the following morning, he was agreeably surprised to find the wires in position, and jointing in progress. On enquiring how it was done, he was informed

"We sent down a rat." Relations were too strained after the slating of the previous evening for further explanation to be sought or voluntecred, but everyone who knew the Underground Inspector of that time, will know that a good story would not be lost for the want of telling. Also it is well known that a frequently repeated story gains "trimmings" on its way, and so the rat quickly became fitted with an "accelerator" in the form of a ferret. According to Mr. Proctor, by the end of the last century, the work of drawing in the twine had been transferred to the ferret, the rat being used as "bait."

And now the very latest version appears in the "Lancashire Daily Post" of yesterday's date (enclosure) from which it will be seen that a squad of ferrets, complete, with collar, drew in the electric lighting cables on the embankment by direct labour, sans twine, sans line, sans gang, sans everything, except a little bit of meat at the farther end of the pipe!

It only remains to disclose the species of rat used on the historic occasion earlier referred to, I believe in 1882. It was not, as was generally accepted, the common "*mus rattus,*" but a different "*mus*" altogether, the "*calamus viminalus,*" a light cane popularly known as rattan, rat for short. It was, as Mr. Stubbs says, before the time of sweeps rods, but these canes which could (and still can) be obtained for a few coppers in about 20 feet lengths doubled in the shape of a hairpin, were frequently used for clearing blocked drains, and similar purposes. The process was known to the workmen as "using a rat," and this is the species of rat from which the ferret and electric trolley have evolved.

By the way, I *would* like a technical description of that electric trolley for carrying cables through ducts, if you could spare the space in an early issue.

Yours sincerely,
W. J. ROLFE.

The following is the extract from the paper referred to by Mr. Rolfe :—

"LONDON'S FIRST ELECTRIC LIGHTS.

"Nobody seems to have noticed that the floodlighting of London has come in what may well be accounted the jubilee year of the electric light. Curiously enough, it was a French firm that introduced electric street lighting to London—the Societé Générale d'Electricité, which charged sixpence an hour for some lights that dazzled and spluttered on the Embankment.

That was rather more than 50 years ago, but it was not till 1881 that electric lighting began to 'take on.' The first provincial town to have it, Godalming, adopted it in that year, and in the same year it was introduced to ships.

I have been given a very interesting account of how the first cables were laid along the Embankment. Nowadays cables are carried through pipes on a sort of electric trolly, but before this idea was hit upon it was not easy to lay cables. The engineer in charge of the Embankment job went into the country one week-end and brought back some ferrets, which he fitted with collars.

Fastening a cable to the collar, he put a ferret in at one end of the pipe and at the other enticed it with a piece of meat. At least, he tried to entice it, but on the whole the ferrets did not rise to the occasion. Sometimes they would emerge minus the cable, sometimes they would go to sleep in the pipe!"

HEADQUARTER'S NOTES.

EXCHANGE EQUIPMENT.

The following works have been completed :—

Exchange.	Type.	No. of Lines
Prestbury	New Auto	240
Folkestone Area (5)	,,	2200
Watford Area (3)	,,	3420
Shepherds Bush	,,	4100
London Auto School	,,	Training Equipment
Pendleton	,,	1620
Westcotes (Leicester)	,,	400
Preston (Brighton)	Auto Extn.	970
Amherst	,,	100
Darlington	,,	700
Moss Side (Manchester) ...	,,	200
Headingley	,,	200

Orders have been placed for the following works :—

Exchange.	Type.	No. of Lines
Bournemouth	Auto Extn.	Observation Equipment
Ewell	New Manual	1220
London Trunk Record and Demand Suite	,,	44 Positions
St. Albans	Manual Extension.	Observation Equipment
R. Taylor (Liverpool)	P.A.B.X.	20
Burnley Corporation	,,	30
Thorpe Meadows (Hastings) ...	,,	20
Morris Cars (Smethwick) ...	,,	50
London County Council ...	P.A.B.X. Extension	300

Exchange.	Type.	No. of Lines
Bishopsgate Tandem	New Auto	Positions
Wolverhampton	,,	Power Plant
Bilton	,,	do.
Blackheath (Birmingham) ...	,,	do.
Broadwell ,, ...	,,	do.
Springfield ,, ...	,,	do.
Stone Cross ,, ...	,,	do.
Sutton Coldfield ,, ...	,,	do.
Stechford ,, ...	,,	do.
Tipton ,, ...	,,	do.
Portslade (Brighton)	,,	do.
Adel	,,	do.
Gibbet Hill	,,	do.
Pinhoe	,,	do.
Park (Dundee)	,,	do.
Bishopsgate Tandem	,,	do.
Priory	,,	do.
Preston (Lancs.)	Auto Extn.	Routiner Equipment
Flaxman	,,	do.
Macaulay	,,	do.
Reliance	,,	do.
Gladstone	,,	do.
Western (London)	,,	do.
Hampstead	,,	do.
Shepherds Bush	,,	do.
Whitehall	,,	do.
Gulliver	,,	do.
Maida Vale	,,	do.
Pollards	,,	do.
Welbeck	,,	Routiner Equipment
Sloane	,,	do.
Temple Bar	,,	do.
Fulham	,,	do.
Bermondsey	,,	do.
Tandem (London)	,,	do.
Bishopsgate	,,	do.
Metropolitan	,,	do.
Holborn	,,	do.
National	,,	do.
Monument	,,	do.
Hendon	,,	do.
Primrose	,,	do.
Amherst	,,	do.
Birmingham (North)	,,	do.
Birmingham (Victoria)	,,	do.
Middlesbrough	,,	do.
Coventry	,,	do.
Hanley	,,	do.
Edinburgh	,,	do.
Ardwick	,,	do.
Brighton	,,	do.
Hove	,,	do.
Leicester	,,	do.
Swansea	,,	do.
Dudley	,,	do.
Sheffield	,,	do.
Rochdale	,,	do.
Southend	,,	do.
Newcastle-on-Tyne (Central) ...	,,	do.
Maidstone	,,	do.
Nottingham (Central)	,,	do.
Sherwood	,,	do.
Basford	,,	do.
Leeds	,,	do.
Arkwright	,,	do.
Blackburn	,,	do.
Manchester (Tandem)	,,	do.
Blackfriars (Manchester) ...	,,	do.
Southport	,,	do.
Torquay	,,	do.

Exchange.	Type.	No. of Lines
Watford	Auto Extn.	Routiner Equipment
Hampstead	,,	Voice Frequency
Western	,,	do.
Ilford	,,	do.
Pollards	,,	do.
Whitehall	,,	do.
Beckenham	,,	do.
Livingstone	,,	do.
Maida Vale	,,	do.
Mitcham	,,	do.
Gulliver	,,	do.
Addiscombe	,,	do.
Gladstone	,,	do.
Shepherds Bush	,,	do.
Metropolitan & National ...	,,	do.
Amherst	,,	do.
Monument	,,	do.
Hendon	,,	do.
Hillside	,,	do.
Primrose	,,	do.
Bishopsgate	,,	do.
Flaxman	,,	do.
Archway	,,	do.
Fairfield	,,	do.
Reliance	,,	do.
Leytonstone	,,	do.
Edgware	,,	do.
Macaulay	,,	do.
Preston Area	,,	Observation Equipment
Brighton Central	,,	2320
Addiscombe	,,	1600
Western	,,	2000
Moss Side (Manchester) ...	,,	200
Linthorpe	,,	300
Portsmouth	,,	100
Epsom	New Manual	3000
Epsom	,,	Power Plant
Pinner	,,	do.
Northwood	,,	do.
Brighton Corporation	P.A.B.X.	30
Torbay Hospital	,,	30
Thrift Stores	,,	30
Nusenbaum & Sons (Newcastle-on-Tyne)	,,	20 lines
Manchester Telephone Service	,,	505 ,,
Northern Aluminium (Banbury)	,,	30 ,,
H. & G. Simonds (Reading) ...	,,	30 ,,
Newcastle-on-Tyne Police ...	,,	30
Crane Bennett (London) ...	,,	30
Arthur Lee, Ltd. (Sheffield) ...	,,	55
Southend Corporation	,,	40

The following items may be of interest :—

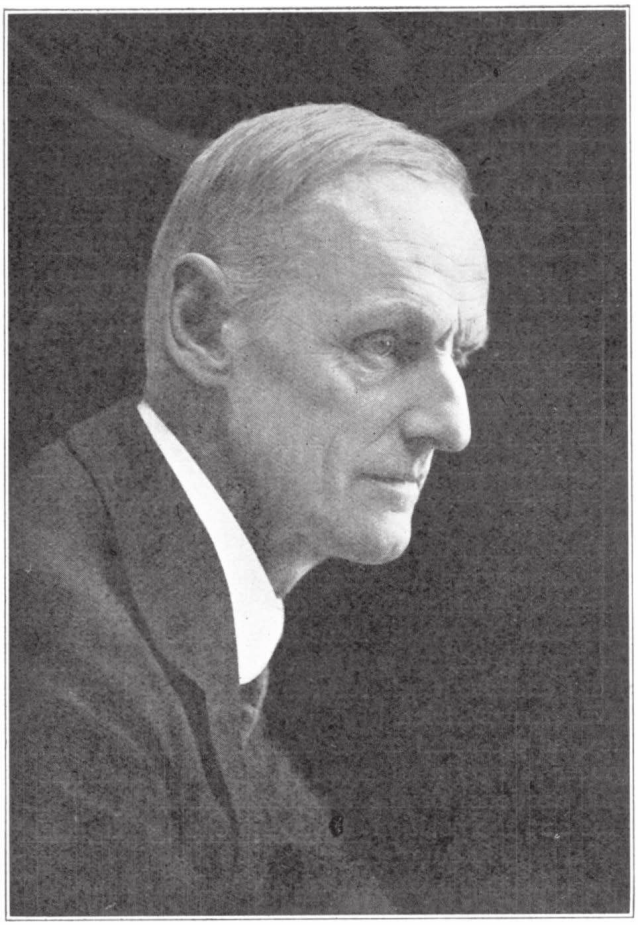
In preparation for the introduction of the " On Demand " system of Trunk Working, which it is proposed to initiate in the near future, 60 positions have been installed on the 5th Floor at the London Trunk Exchange.

The new system of Toll Junction operation whereby Toll calls are dealt with at the originating Exchange on a " no-delay " basis, is being introduced in Exchanges in London within the 5 mile area, and the conversion of a number of positions at various exchanges is now being proceeded with. In this connection, an ingenious time check known as a

"Chargeable Time Indicator" has been devised. The maximum number of cord circuits on Toll Control Positions is 10, and the Operator can ascertain the duration of a call connected by any one of these cord circuits by throwing the relative key. Strips of lamp jacks are mounted in the panels in front of the Operator, and the duration of the call at any given moment is indicated in minutes by illuminated figures.

The effective lighting of Apparatus Rooms in telephone exchanges has long been an engineering problem. Portable hand-lamps and lamps on running leads, in addition to the general lighting, have been tried with little success. The introduction of the Automatic system and the supersession of the "Selector Board" type of equipment by single-sided apparatus racks has called for the adoption of new methods. A system of flood-lighting of the racks has now been developed, and it is being installed in new exchanges. Lamps and reflectors are fixed to the ironwork of the racks and are independent of the ceilings or walls. The difficulties of arranging the lighting points, before the erection of plant, in the most effective position, and ensuring their freedom from the obstructions of apparatus and cable racks, are thus overcome, and the results of the experiment will be watched with considerable interest.

MR. P. T. WOOD.



MR. P. T. WOOD.

MR. P. T. WOOD was educated at the Liverpool College Upper School and largely as a result of a visit from a phrenological friend of the family was diverted from the University career enjoyed by four brothers to the more exacting profession of the electrical engineer.

He entered the service of the National Telephone Co. in October, 1894, under Mr. W. M. France, who was the Chief Electrician at Liverpool at that time. In the next six years he acquired a practical knowledge of apparatus fitting and maintenance and of exchange construction and maintenance which is not generally possible in these days of specialization. In October, 1900, he resigned his position as Exchange Inspector to take up duties with the United River Plate Telephone Co. as Assistant Chief Electrician, and was engaged in Buenos Aires on exchange construction and underground development work till February, 1903, when he resumed with the National Telephone Co. in London, taking up the post of Assistant City Electrician vacated by Mr. F. P. Edmonds on his transfer to the Traffic side. He recalls the responsibility resting on him for the successful operating of the unveiling mechanism on the occasion of the unveiling of the memorial to Michael Faraday by Lord Kelvin on November 24th, 1906. Throughout this period and for 14 years he lectured on Telephony at the Northampton Institute.

In 1907, on the reorganisation of the London District, he was promoted to the position of Assistant Metropolitan Electrician, which position he held at the transfer when he was graded as Executive Engineer and took charge of the newly formed Central Internal Section. Throughout the strenuous years of the war the Telephone Stations under his responsibility grew to the one hundred thousand figure, largely as a result of the mushroom growth of Government Departments. His duties brought him in contact with many men of national importance and he remembers with satisfaction Lord Curzon commenting on his similarity of features to a cousin, at one time a member of his Lordship's Indian Secretariat. He has also had the honour and

pleasure of attending in an official capacity on His Royal Highness the Prince of Wales, and holds an interesting memento of the first time a member of the Royal Family broadcast, viz., on the occasion that the Prince of Wales broadcast a message to Boy Scouts in October, 1922.

During this period he served in the Post Office Special Constabulary, attaining the rank of Chief Inspector. In this capacity he had the honour of being presented to their Majesties the King and Queen at a Garden Party held in July, 1919.

He was transferred to the Engineer-in-Chief's Office in March, 1924, as Assistant Staff Engineer and was responsible for the initial organisation of the new Standards Group in the Equipment Section and became a member of the Committee, under the chairmanship of Mr. Ramsay, that brought to a successful conclusion the preliminary studies of the London Automatic system.

His hobbies are unconnected with the hitting of a ball, as he prefers the less strenuous country walk and can still manage a 40 mile tramp without discomfort. He is interested in cabinet making and philately.

MR. H. KITCHEN.

MR. H. KITCHEN.

MR. KITCHEN was appointed telegraphist at Newcastle-on-Tyne in 1889, and during the succeeding seven years he acquired a fundamental knowledge of the telegraph and telephone systems in use during that period.

After successfully negotiating a departmental examination (an innovation at the time) he was transferred to the Engineering Branch and appointed to the East Dean Repeater Station in 1897. He advanced to Haverfordwest in 1898, was made 2nd Class Engineer in 1901 and returned to Newcastle. Here his activities were concentrated in particular in the replacement of an underground system of gutta-percha covered conductor with lead-covered air space paper core cables, and in opening new telephone exchanges in the northern part of the county of Durham.

Executive Engineer rank was attained in 1911. At the 1912 transfer he took charge of the rearranged Newcastle Section and lived a strenuous life for some years afterwards in co-ordinating the plant taken over from the National Telephone Co. with that of the Post Office.

For some years he conducted evening classes in electrical communication subjects under the Durham County and Newcastle Educational Authorities.

During the war he was gazetted Lieutenant R.E. and did effective work for the Army and Navy in the Northern District.

He was promoted to the class of Assistant Staff Engineer in 1925 and served in the Lines and Telegraph Sections of the Engineer-in-Chief's Office. He took up the position of Superintending Engineer at Edinburgh in August last.

Mr. Kitchen has been a member of the Board of Editors of this Journal since 1926.

PER ARDUA AD ASTRA.

C.J.F. Pitcher, S.C. Pugh, A.W. Stonebanks, C.A.L. Nicholls, L.R. James, C.E.C. Watling, S.J. Edwards, R.F. Goodchild, A.H. Ellenden, W.K. Dunn, J. Prescott, W.F. Porter, F. Leach, J. Atkinson, A.D. Carrette, A.F.E. Evans (School Staff), E.A. Magee, W.H. Owens, J.M. Cambridge, J.E. Judson, G.R. Sudell (School Staff), A.B. Marsden, W.N. Maddison, R.E. Reed, L.R. Watson, G.E. Button, L.J. Trott, D.F. Hamilton, W.H. Dolan, A.E. Fairs, A.F. Turner, N.V. Knight, G.H. Fogg, C.H.J. Fleetwood (School Staff), R.M. Rentax, W. Prickett, H.A. Turner

P.I's. COURSE
MAY – AUG. 1931

FROM one of 34 Probationary Inspectors, successful candidates at the December 1930 Examination, a few impressions of the first period of training may be of interest.

All had received the official notification of success and had been ordered to report for training at the Engineer-in-Chief's Training School, situated at the Research Station, Dollis Hill. A considerate School Staff had arranged for one of its members to meet us at the main gate of the station and escort us to the lecture hall where we proceeded to make each other's acquaintance. Whilst awaiting the reception lecture, we indulged in a mutual cross-examination, recalling experiences and comparing notes *re* our former occupations. In the course of his official welcome, Captain Cohen gave an interesting lecture dealing with the scope of the Department's activities. He impressed us with the magnitude of the Engineering Department, and did not fail to bring relief to some of our members who had been—as it were—waiting for the dentist.

The main lecture hall, a truly magnificent place, had been allotted to us for our studies during our subsequent stay at Dollis Hill. In it we met our lecturers—specialists in all branches of the Department's work. Each informed us, with a few exceptions, that his particular subject was the most important. We now realise that all are integral parts of a great machine. The writer, although not anxious to tread the same path again, has been greatly impressed by the way in which most lecturers achieved the almost impossible task of creating interest in very " dry " subjects. If the reader of this article will refer to the " Journal " of October 1930, and scan the syllabus laid down for the training of Probationers in the Engineering Department, he will on learning that this syllabus is completed within sixteen weeks, agree that the persons responsible for its completion are worthy of the highest praise.

The proportion of time allowed for the study of different phases of the Department's practice did

not always appear satisfactory, but perhaps the writer's interests are biassed in certain directions.

During the period devoted to the study of non-technical subjects, it seemed that an Inspector had at some time or other to check and sign every form devised and issued by the Department, but subsequent lectures showed that not a few are dealt with by other members of the Organisation. Whenever, on future occasions, one of us is called upon to make use of any particular form, a mental picture of the lecture hall at Dollis Hill Research Station will appear and recall occasions when he was led, rather hurriedly, it is feared, through the procedure surrounding innumerable forms. Then perhaps detail which now seems lost under a mass of information acquired since, will return to be of use and he will have cause to bless the lecturers who so valiantly endeavoured to shed some light during the course of training.

To many of us the technical lectures covered new ground, to others they created memories of days of toil and sleepless nights of study. None can say he learnt nothing. The lecturers generally showed themselves to be expert in their subjects and invariably impressed us with their own vast knowledge. The lectures were on the whole interesting and informative, and it is to be regretted that the time allowed for dealing with certain subjects was totally inadequate and prevented a more thorough absorption of the practical details and theoretical considerations involved.

On several occasions arrangements were made for visits to various internal and external works. Here was seen the need for organising along the lines already defined by our lecturers. Although it should not be inferred that conditions of inefficiency were found, close observation showed that a tight grip on departmental matters was vital. These visits certainly are an asset to the Probationer, for by them he is able to observe the methods of applying the many rules of administration and thus to solve any difficulties which may have arisen during his studies.

Towards the end of the course, visits were made to Contractors' Works to witness the manufacture of cable and other telephone plant. These gave excellent opportunities to study first hand the methods adopted on the part of the Contractors to meet the requirements of the rigid Post Office Specifications.

By the time this article is in print we will be engaged in district training, the District in each case having been chosen as far as possible to suit the convenience of the Probationer. This again shows the consideration paid by the Department to the interests of its new officers as well as to its own.

Our experiences in our new sphere are difficult to foretell, but although each one of us will be functioning in a different district in some cases hundreds of miles apart, we may abide in the knowledge that co-ordination and co-operation are the two basic features underlying the success of the Post Office Engineering Department. Mr. C. W. Brown and his School Staff and other members of the Department have, during our stay at the Training School demonstrated this, and the beneficial effects that result.

Upon the even of completion of the course, Captain B. S. Cohen addressed us, and in a few well chosen words wished us success in the future He stressed the inadvisability of losing touch with the rapid progress in Communication Engineering and, in pointing out how easy it is to get into a rut, urged us not to do so. We can assure him that whatever course our future may run the splendid impetus given by the training at Dollis Hill can only reflect to the credit of the School.

It only remains to express the keen appreciation felt by these 34 students of the welcome extended to them by the School Staff and the efforts of the Research Station generally to make them feel at home.

L.R.J.

LONDON DISTRICT.

Growth of Telephone System.—During the quarter ended 30th June, 1931, the nett additions in exchange lines and stations amounted to 4,015 and 7,669 respectively. The total is now 417,097 exchange lines and 703,777 telephone stations.

The total loop mileage of telephone wire, including trunks and junctions, is 1,548,428. An additional 155 kiosks were erected during the quarter.

New Manual Exchanges.—Two further manual exchanges to cater for the increasing demand for telephone facilities in the outlying suburbs were opened in July.

Sanderstead exchange, installed by the General Electric Company, Limited, with an initial multiple capacity of 1800 and ultimate of 10,000, was opened on July 15th by the transfer of 757 subscribers from the Purley, Croydon and Upper Warlingham exchanges.

On July 29th, Downland Exchange, installed by the Automatic Telephone Manufacturing Company, Limited, was opened to serve the rapidly developing neighbourhood around Merstham and Coulsdon. The initial multiple capacity of the exchange is 1,100 and ultimate 5,000; at the opening 477 subscribers' lines from the hypothetical Downland Exchange on Merstham and from Purley and Burgh Heath exchanges were successfully transferred.

L.E.D. Intercommunication P.A.X.—In a complicated telephone network such as that in London it is essential that communication between the

various automatic and manual exchanges be effected by other means than the public system for ensuring quick and efficient co-operation in the advising and clearing of faults, especially in the case of major breakdowns.

Since the inauguration of automatic working in London each automatic and C.C.I. exchange has had a private wire to the Tandem exchange terminating on a magneto switchboard and has thus been able to establish connection with any other exchange in the network. It was considered, however, that the magneto system was not entirely satisfactory as regards reliability and speed of connection, so steps were taken to introduce automatic working in the form of a P.A.X. separate from the public system.

This P.A.X. has been installed by the A.T.M. Co. in the Holborn Exchange and comprises the following main items of equipment :—

140 Preselectors with capacity for 200.
25 1st Selectors with capacity for 30.
and 34 Final Selectors with capacity for 60.

Each automatic and C.C.I. Exchange has two stations on the one line to the P.A.X., an indicator and dial on the Test Desk and a telephone in the apparatus room. Party line working is provided by allotting two final selector numbers per exchange on the P.A.X., the X and Y ringing feature being catered for by special jumpering. At present 111 exchanges are connected to the P.A.X. Thorough tests were carried out at each exchange in co-operation with the P.A.X. before the transfer, the receipt of incoming calls, correct dialling out and transmission being verified in every case.

The transfer was effected by the change over of heat-coils on the Holborn frame at 8.15 a.m. on Wednesday, the 19th August. From 8.15 a.m. till 9 a.m. the magneto telephones in the apparatus rooms were changed for automatic type and during the day test calls were passed to neighbouring exchanges to verify the correct conditions.

The introduction of the P.A.X. will enable close and speedy co-operation between all exchanges to be effected and should amply justify the capital cost and maintenance charges involved.

Teleprinter Pool: Tandem Centre.—It may be of interest to some of our readers to learn that a pool of teleprinters and auxiliary apparatus for use at events such as Race Meetings, Regattas, etc., has been formed, and this apparatus is located in the Central Telegraph Office Section.

Teleprinters of varying D.C. voltages, with baseboards having connections which can be utilized to allow of Simplex, Duplex and Omnibus working, are available and rectifiers from A.C. to D.C. are stocked. Ultimately, small petrol electric sets with accumulators will be available in order that Teleprinters of a standard voltage can be used anywhere. The London Centre supplies the needs of the South-Eastern counties.

Pneumatic Perforators.—The last of the pneumatic perforators used in connection with high speed Wheatstone working at the C.T.O. has been recovered. Pneumatic perforators were installed in the News Division in the London Head Telegraph Office over 40 years ago, and were employed chiefly on News transmissions. Changes in their construction have been made from time to time since those early days, the later double type being capable of punching eight Wheatstone slips simultaneously. The withdrawal of the perforator is the result of the general development in the handling of telegraph work by means of Teleprinters.

MR. J. BROWN, M.I.E.E.

Mr. J. Brown, Assistant Superintending Engineer, London Engineering District, who retired on the 30th June, 1931, was one of the band of Scotsmen who invaded the Engineering Department in the "nineties," and whose ability and genius contributed in no small degree to the proud position which the Department occupies at the present time.

Mr. Brown was born and educated at Aberdeen and entered the Post Office Telegraph Service in 1885. Although he was active in most forms of sport he did not neglect technical study, and after numerous successes in this direction he was transferred to the Engineering Department at Liverpool in 1898. A year later he was promoted to Sub-Engineer at Warrington, where he carried out many important engineering works in Lancashire, Cheshire and North Wales. 1903 found him in London as Second Class Engineer engaged with many others in the task of telephoning the Metropolis.

After this he was for several years in the Hornsey Section, first as Assistant Engineer and later as Executive Engineer, leaving there in 1912 to take charge of the Technical Section of the London Engineering District. In this capacity he was responsible for the standardisation of procedure and the co-ordination of the organisation of the National Telephone Company with that of the Department. The organisation set up at this time by Mr. Brown for dealing with the design and lay-out of plant to meet telephone development in London and its suburbs has remained practically unaltered to the present time—a remarkable tribute to the character of his work.

During the war he was placed in charge of the

Mr. James Brown.

Centre External Section, where the promptitude and efficiency with which lines of communication between the nerve centres of the Empire in Whitehall were proved earned high praise from the War Office, Admiralty and other Government Departments. After the war extensive proposals for overtaking telephone development and schemes for the intensive training of the staffs occupied Mr. Brown's attention. In 1927 he was promoted to the rank of Assistant Superintending Engineer and was put in control of external construction. He rendered invaluable service in connection with the fires in the Embankment Subway and the water burst at St. Giles' Circus, where the Department's plant suffered serious damage. The gas explosion in the Post Office Holborn tube provided an opportunity at the close of his official career of proving his capacity for dealing with difficult problems. Practically all the details in connection with the official enquiry and the subsequent settlement claims were dealt with by Mr. Brown. He was a tactful negotiator and carried through successfully many important Wayleave settlements with public authorities in London. In very few cases was it necessary to appeal to the Courts and the Department never lost a court case for which Mr. Brown was responsible.

Sir R. W. Woods, the Post Office Solicitor, in a letter which was read at the official farewell to Mr. Brown, expressed on behalf of himself and his staff their keen appreciation of the invaluable assistance given by him in many important cases and their regret at losing such a pleasant colleague and companion. In Mr. Brown the Department loses a highly efficient engineer, a wise administrator and one who will long be remembered for his fairness and readiness to help others, and who has endeared himself to all by his kindliness and charm of manner. May he have many happy and useful days in his retirement.

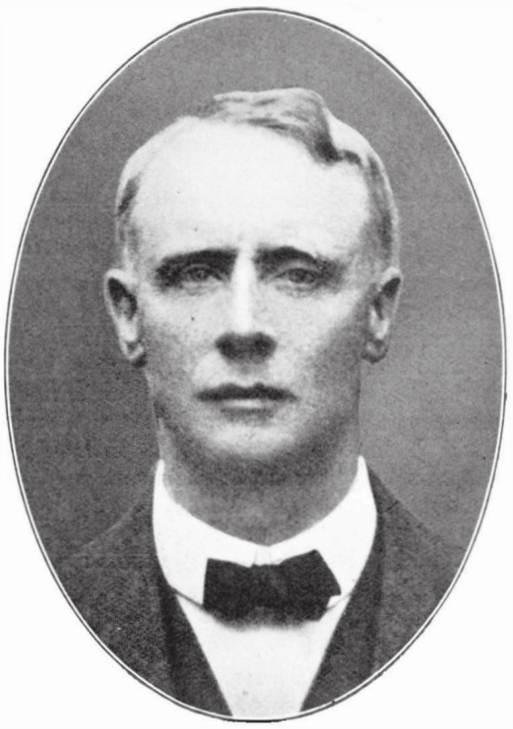
LOCAL CENTRE NOTES.

NORTHERN CENTRE.

Summer Outing, 7/7/31.

The above photograph was taken on the occasion of the Sixth Annual Summer Outing of the Northern Centre, when a party of 66 members and friends, retired officials and representatives of the Commercial Staff visited Cragside Rothbury, where tea was served by kind permission of Lord Armstrong.

RETIREMENT OF MR. J. D. TAYLOR.



Mr. J. D. Taylor.

Mr. John Dean Taylor, for 19 years Superintending Engineer of the Scotland East District, retired from the service on 15th August, 1931, on attaining the age of 60.

Mr. Taylor was born at Scarborough, but his parents removing to Leeds he entered the Post Office there in 1886, and this enables him to tell some amusing stories of those "sixpenny tariff" days in which the late Mr. E. Trenam figures pleasantly—and, as a rule, effectively! In 1891, after a period of temporary duty in the Engineering Department, he was transferred to the clerical staff of the Superintending Engineer, Mr. J. C. Chambers; and two years later he was promoted and transferred to Cardiff as a 1st Class Junior Clerk.

The acquisition of the telephone trunk lines from the National Telephone Company, in 1896, provided an opportunity for temporary employment on engineering duties, followed by promotion in 1897 to a 2nd Class Engineership at Manchester: two years later, Mr. Taylor was transferred to the Engineer-in-Chief's Office as one of the group of engineers selected by Mr. (afterwards Sir) John Gavey to make the survey of the underground plant necessary to the "Telephoning of London" by the P.O. His association with this important instalment of the State telephone service continued for eight years and the knowledge thus gained of the economic principles governing the lay-out of "local" underground plant and of the difficulties encountered in congested areas, proved of great value later.

In 1907 Mr. Taylor returned to Leeds as Assistant (Superintending Engineer) to the late Mr. G. M. Carr; and in 1912, after a strenuous terminal period of detached duty connected with the inventory and valuation of the National Telephone Company's plant, he crossed the Border—in a direction not regarded as normal—and, with headquarters at Edinburgh, entered on the last stage of his official career.

The changes and advances which have taken place in the electrical communication network of the east and north of Scotland during Mr. Taylor's régime are of great significance, whether expressed statistically or in other ways: the most important, perhaps, from one standpoint, has been the extension of the telephone trunk system northwards from Tain to Wick, Thurso and the Orkneys; from another, the tripling of the mileage of underground conductors; and, from yet another, the entirely successful conversion, in 1926, of the Edinburgh telephone exchange system from manual to automatic working—at that date, the largest scheme of the kind which had been undertaken and one with which, as Mr. Taylor is first to acknowledge, the name of the late Mr. R. Alexander will always be associated.

On the economic side, there are few—if any—laurels which during the past 10 or 12 years have not been gained by the Scotland East District; and the success achieved may rightly be attributed to Mr. Taylor's unremitting efforts to secure "good work in good time." In some of his views on procedure he inclined towards a drastic curtailment of checks and safeguards; and time may show that his assessment of the risks was accurate or, in other words, that his judgment was sound.

Mr. Taylor was a member of the Committee of Superintending Engineers and also the Committee of the Scottish Centre of the Institution of Electrical Engineers: in these capacities he rendered the same good service as in the discharge of his main responsibility.

It is frequently both easy and convenient, in a notice of this kind, to distinguish between the official and the man: in this instance, such a distinction is impossible. Mr. Taylor's outlook on life is uniform in all directions and comes of his qualities—honest; sincere; strong: such a man expects efficiency from his staff and, better still, he stimulates it—when a mistake occurs, he aims to correct it, but he aims also to locate the cause, believing that in realisation of the cause lies the best chance of preventing recurrence. A deep sympathy with those in trouble, a well-marked sense of humour and a life-long and active interest in healthy sport are other components of the man.

Mr. Taylor may feel assured that, in leaving the official circle, he takes with him the best wishes of his many friends, both within and without the Scotland East District. J.W.A.

COMMONWEALTH OF AUSTRALIA.

POSTMASTER-GENERAL'S TWENTIETH ANNUAL REPORT, FOR YEAR ENDING 30th JUNE, 1930.

THE following extracts from the above report will be of interest to communication engineers :—

CAPITAL INVESTMENT.

The total amount debited to Capital Account for fixed Assets and Plant at the commencement of the year 1929-30 was £49,265,641.

The Capital expenditure during the year totalled £3,509,652 under the following headings :—

	£
Telephone Lines and Equipment (excluding Trunk Lines) ...	2,539,013
Telegraph Lines and Telephone Trunk Lines	490,198
Telegraph Equipment	104,494
Postal Equipment	85,791
Miscellaneous Plant and Equipment	45,885
Sites, Buildings, Furniture, and Office Equipment	244,271
Total	3,509,652

TELEPHONE SERVICE.

As a result of the adverse business and financial conditions, the telephone service did not progress at the same rapid rate as in former years. 11,567 lines and 14,890 telephones were added during the year, bringing the total lines and stations in use to 395,812 and 520,169 respectively. Australia has now an average of 8.08 telephones per hundred people and occupies sixth place in the list of countries having the greatest telephone density.

183 new telephone exchanges were brought into service and there are now 6,094 exchanges in operation. 5,946 of the exchanges are in areas outside the capital cities, and they serve nearly 44 per cent. of the total telephones connected throughout the Commonwealth.

The abnormal conditions also affected telephone traffic and the increase in business was not so great as in previous years. During 1929-30 420,639,538 effective paid local calls were made, an increase of 14,685,900 on the preceding year. 35,388,715 trunk line calls were also effected in comparison with 34,741,671 in 1928-29.

171,557 miles of wire were added, bringing the total length of telephone wire to 2,482,149 miles.

Rural Automatic Exchanges.—The trials with automatic equipment designed to meet the conditions peculiar to rural areas have continued. Unfortunately, the financial position renders it necessary to defer for the time being the installation of additional units.

Long Distance Service.—Not only were 8,759 miles of telephone trunk line added to the system during the year, but extra channels on many important routes were secured by the installation of the carrier system. There are now thirty-two carrier telephone systems in operation in Australia, giving a total of sixty channels, with an aggregate channel mileage of approximately 19,000 miles.

The completion during the year of carrier telephone systems from Brisbane to Townsville and from Townsville to Hughenden, has extended the long distance communication system to Northern Queensland. Telephone calls from Adelaide are now possible to Hughenden and Cairns.

The work of providing a telephone link between Adelaide and Perth, a distance of 1,700 miles, is in progress, and it is hoped to inaugurate the service before the end of 1930, when the ideal of a nation-wide telephone service will be within sight of achievement.

Overseas Telephone Service.—Another milestone of telephone progress was passed when commercial telephone service was established during the year between Australia and Great Britain. The inauguration took the form of a conversation between the Prime Minister of Great Britain, the Honorable J. Ramsay MacDonald, and the Prime Minister of Australia, the Honorable J. Scullin, which was held at 5.30 p.m., on 30th April, 1930. Since then, the service has been extended to many other European countries, and to the United States and Canada. It is hoped to open a service with New Zealand shortly and preliminary tests are proceeding.

Whilst the utility of the service with Europe is restricted somewhat because of the differences in time, nevertheless it furnishes an important link in the rapidly growing network of a world-wide telephone system.

New Automatic Exchanges.—Twelve new automatic exchanges were placed in service during the year, with 24,390 lines.

Research.—The Research Section continues to provide expert technical assistance with the developmental and investigatory problems of the telegraph, telephone and radio services of the Department. During the year it was found necessary to acquire additional accommodation for the increased staff and additional equipment.

The total staff at 30th June, 1930, was 22 officers, and the value of the equipment £16,000.

Transmission Section.—During the year a special section was formed to deal with all transmission questions. The specialized treatment of the important technical matters falling under this heading has already had beneficial effects and it may be

expected that the Department's plant will function with greater efficiency as a result of the concentrated study given to this vital aspect of the service.

Telegraphs.

Traffic.—The number of telegrams lodged during 1929-30 for transmission to places within the Commonwealth was 15,724,246 as against 16,345,152 for 1928-29, a decrease of 620,906, or 3.80 per cent.

These figures are inclusive of free messages (service, meteorological and shipping), the proportion representing paid traffic being 14,566,965 messages for 1929-30 as against 15,220,947 for 1928-29, a decrease of 653,982, or 4.30 per cent. The receipts from the paid traffic totalled £1,131,249 for 1929-30 as against £1,196,754 for 1928-29, a decrease of £65,505, or 5.47 per cent.

The number of telegrams despatched to places beyond the Commonwealth was 781,982 for 1929-30 as against 808,812 for 1928-29, a decrease of 26,830 or 3.31 per cent. Telegrams received from abroad for delivery in the Commonwealth totalled 718,339 for 1929-30 as compared with 727,256 for 1928-29, a decrease of 8,917, or 1.23 per cent. The Commonwealth earnings on traffic destined for or received from abroad were £205,700 for 1929-30 as against £221,358 for 1928-29, a decrease of £15,658, or 7.07 per cent.

Picturegram Service.—A picturegram service was opened for public business between Melbourne and Sydney during the year. The transmission of a photographic image of 70 square inches, effected over an existing telephone carrier channel 560 miles in length, occupies fifteen minutes only, the image being of good quality. Notwithstanding the severity of the prevailing depression, 400 images were exchanged between the two cities during the year.

Machine Printing Telegraph Systems.—The policy of extending the direct machine printing services wherever economically justified has been pursued throughout the year. The machine speeds have been steadily increased, the systems between Melbourne, Sydney and Adelaide now being operated at 50 words per channel minute.

Telegraph Carrier Outlets.—The financial advantages as well as the stability in performance of carrier wave transmission on well maintained aerial routes are reflected in the rapidly extending use of the carrier system on important traffic routes. The telegraph carrier system between Adelaide and Perth, now nearing completion, will be available for use early in 1931, providing Perth with direct machine-operated outlets to Adelaide, Melbourne, Sydney and, later, Brisbane. On completion of the work, the Department will reap important service and economic advantages.

Radio Services.

National Broadcasting Service.—The inauguration of the National broadcasting service was made with the transference of the services from station 2FC Sydney on the 17th of July, 1929, and satisfactory progress has been made to date by bringing the following stations within the National scheme on the dates indicated :—

2BL Sydney, 22nd July, 1929.
3LO Melbourne, 22nd July, 1929.
3AR Melbourne, 8th August, 1929.
6WF Perth, 1st September, 1929.
5CL Adelaide, 14th January, 1930.
4QG Brisbane, 30th January, 1930.

The only remaining station to be brought within the National service is 7ZL Hobart, which will be taken over after the expiration of the existing licence on the 13th of December, 1930.

The responsibility for the provision of the programmes over the whole of the National service stations was assumed by the Australian Broadcasting Company under a contract with the Commonwealth Government. At the present time the Company is rendering programmes throughout the Commonwealth covering about 30,000 hours per annum.

The first year of the National broadcasting service has unfortunately been one in which the economic conditions of the Commonwealth have been seriously depressed, but even under the adverse conditions the number of licences has increased from 301,000 to 312,000.

The Post Office is responsible for rendering all the technical services under the National broadcasting scheme, embracing the stations, studios, pick-up equipment, and inter-connecting lines.

FEDERATED MALAY STATES.

Extracts from the Annual Report of the Posts and Telegraphs Department for year 1930 :—

Telegraphs.

During the year 383,887 telegrams were despatched and 412,017 telegrams were delivered, being a decrease of 12 per cent. in the number of telegrams despatched and a decrease of 11 per cent. in the number delivered as compared with 1929. The revenue derived from telegrams was $386,417. The revenue shows a decrease of $58,981 or 13 per cent. compared with that of 1929. The value of telegrams sent free of charge for Government departments was $52,205, an increase of $10,300.

Telegraph facilities were extended to the new post offices at Malim Nawar and Gambang and, as it was not practicable to connect Sungei Lembing with the ordinary telegraph system, a low-powered short-

wave Marconi type ZSB 2 station was installed in the post office and opened for traffic on the 3rd of November. A telegraph office was opened at Kuala Pahang on the 20th of August.

The use of typewriters for the reception of telegrams was further extended with satisfactory results.

In conjunction with the Eastern Extension Australasia and China Telegraph Company, Limited, arrangements were again made for the acceptance at any telegraph office in the Federated Malay States of "Christmas and New Year Greeting Telegrams" for many countries, at rates which approximated to one-quarter of the ordinary charges.

Telephones.

The number of direct exchange lines connected to the Federated Malay States telephone system on the 31st December, 1930, was 5,181, an increase of 106 as compared with 1929. In addition there were 2,617 extension lines, extension bells, private lines, private bell or alarm circuits and tell-tale clock circuits maintained by the department in 1930 as compared with 2,403 in 1929.

The revenue derived from telephones was $1,323,437, a decrease of $29,498 compared with 1929. Of this revenue the amount derived from junction and trunk services was $402,894, a decrease of $60,261 below the previous year.

On the 31st December, 1930, 66 public telephone exchanges were in operation in the Federated Malay States. By the end of the year 99 public call offices were available at post offices and postal agencies in the Federated Malay States—an increase of four over 1929.

The approximate total originated telephone traffic during the year 1930 was as follows :—

Local calls	14,247,000
Junction calls	2,061,000
Trunk calls	995,000
Total originated traffic ...	17,303,000

The installation of the new automatic exchange for Kuala Lumpur was commenced by Messrs. Ericssons Telephone Manufacturing Company, Limited, on the 3rd July, 1930, and was nearing completion by the end of the year.

The question of utilising automatic exchange equipment in rural areas has continued to occupy the attention of the department during the year, and two additional "Rural Automatic Units" have been ordered for trial under service conditions—one at Gap and one at Temerloh.

The scheme under consideration in 1929 for the provision of "Carrier Current" speech channels between Singapore and Kuala Lumpur, Singapore and Bukit Mertajam, Kuala Lumpur and Bukit Mertajam, and Ipoh and Bukit Mertajam (to which has been added a single channel system between Singapore and Tampin) was authorised by the Straits Settlements and Federated Malay States Governments during the year and a contract for the necessary equipment was placed with Messrs. Standard Telephones and Cables, Limited, of London, on the 24th May, 1930, and the contractors had commenced installation on site by the end of the year.

Wireless.

One hundred and seventy-nine temporary licences for the use of wireless receiving apparatus were issued during the year and two experimental transmitting licences. The British official news broadcast from the wireless station at Rugby in England, received at Penang wireless station and retransmitted from Penang by land-line for delivery to local newspapers on payment of a monthly fee, averaged 26,245 words a month.

A Marconi type U. ½ K.W. telegraph-telephone transmitter was reconstructed and re-modelled as a broadcast transmitter to operate upon 325 metres and installed in the Petaling Hill Station.

A low-power short-wave Marconi type ZSB 2 station was installed at the Post Office at Sungei Lembing and opened for traffic on the 1st of November.

Two Marconi ¼ K.W. type XMD 1 sets were sold to the Kedah Government and installed by this department at Alor Star and Pulau Langkawi. The service was opened in July and is reported to be satisfactory.

BOOK REVIEW.

"Examples in Power Distribution and Electric Traction." By A. T. Dover, M.I.E.E., A.Am.I.E.E. (Sir Isaac Pitman & Sons, Ltd.). Pp. 80. Price 3/6.

This book deals briefly with the more important theorems and formulæ relating to Power Distribution and Electric Traction, supplemented by typical questions, set by the University of London, the C. and G. Institute, and the I.E.E., to which answers are given. It will prove useful chiefly to students preparing for the higher examinations set by these bodies.

J. McG.

I.P.O.E.E. PROGRAMME, 1931-32.

PROVISIONAL PROGRAMMES OF LOCAL CENTRES.

LONDON CENTRE.

1931.
6 Oct. J. S. ELSTON, A.M.I.E.E.
"Trunk Telephone Re-organisation Plan."
10 Nov. W. T. PALMER, B.Sc., Wh. Ex., A.M.I.E.E., and E. H. JOLLEY, A.M.I.E.E.
"Telephone Cable Testing."
8 Dec. G. J. S. LITTLE.
"Electric Wave Filters."

1932.
12 Jan. W. E. H. KENNEDY.
"Industrial Psychology and its possibility in the P.O.E.D."
9 Feb. F. H. BUCKLAND and R. H. FRANKLIN.
"Cable Manufacture."
8 Mar. R. T. A. DENNISON.
"P.B.X. Installation, requirements governing design of auto equipment and their practical applications."
10 May G. F. O'DELL, B.Sc. (Eng.), M.I.E.E.
"Standardisation."

Informal Meetings.

1931.
27 Oct. R. E. SOPER.
"Special features in U.G. contract work."
24 Nov. H. T. ROBERTS.
"Engineering Repair Service."

1932.
26 Jan. G. EVANS and S. W. BROADHURST.
"The By-path System of Automatic Telephony."
23 Feb. HARVEY SMITH.
"Something new in Cabling and Jointing work."
22 Mar. *To be arranged.*
26 Apr. E. J. WILBY, M.I.E.E.
To be announced later
Visits:—
P.O. Research Station, Dollis Hill.
B.B.C. Broadcasting House.

EASTERN CENTRE.

1931.
29 Sept. N. F. CAVE-BROWNE-CAVE, B.Sc., M.I.E.E.
"Sound and Hearing."
24 Nov. J. S. ELSTON, A.M.I.E.E. (*E.-in-C.O.*).
"Trunk Telephone Re-organisation Plan."

1932.
W. E. H. KENNEDY (*E.-in-C.O.*).
"Industrial Psychology and its possibilities in the P.O.E.D."
16 Feb. C. J. JONES.
"Fenny Stratford Repeater Station."
15 Mar. T. FEWSTER (*Northern*).
"District Accounting."
12 Apr. L. G. SEMPLE, B.E.
To be arranged.

NORTHERN CENTRE.

1931.
7 July Summer Visit.
21 Oct. J. S. ELSTON, A.M.I.E.E. (*E.-in-C.O.*).
"Trunk Telephone Re-organisation Plan."
18 Nov. T. FEWSTER.
"District Accounting."
16 Dec. A. O. GIBBON, M.I.E.E. (*E.-in-C.O.*).
"The Control of Electrical Time Services in the British Post Office."

NORTHERN CENTRE—*continued.*

1932.
30 Jan. Prof. W. M. THORNTON, O.B.E., D.Sc., D.Eng. M.I.E.E.
"Transients."
17 Feb. *To be arranged.*
20 Apr. N. F. CAVE-BROWNE-CAVE, B.Sc., M.I.E.E. (*Eastern Centre*).
"Non-Metallic Materials and their characteristics."

NORTH EASTERN CENTRE.

1931.
— *To be arranged.*
10 Nov. J. S. ELSTON, A.M.I.E.E. (*E.-in-C.O.*).
"Trunk Telephone Re-organisation Plan."
— *To be arranged.*
— *To be arranged.*
— *To be arranged.*

NORTH WESTERN CENTRE.

1931.
— Sept. Visit to North Regional Station (B.B.C.).
26 Oct. J. M. SHACKLETON, M.I.E.E., and J. K. MURRAY, M.I.E.E.
"Co-operation."
8 Dec. J. S. ELSTON, A.M.I.E.E. (*E.-in-C.O.*).
"Trunk Telephone Re-organisation Plan."

1932.
11 Jan. G. S. SUNLEY.
"Postal Organisation."
15 Feb. T. E. TOOTELL.
"Transmission Testing in Telephone Exchanges."
14 Mar. J. D. TOUGH.
"Preliminary work in connection with the transfer of Exchange Systems."

SOUTH LANCS. CENTRE.

Not yet available.

NORTH MIDLAND CENTRE.

1931.
29 Sept. "Long Distance Radio Telegraphy" (at Rugby Wireless Station).
2 Nov. J. S. ELSTON, A.M.I.E.E. (*E.-in-C.O.*).
"Trunk Telephone Re-organisation Plan."
7 Dec. H. GREEN, A.M.I.E.E. (*Standard Telephone & Cables, Ltd.*).
"The Installation of the London-Liverpool Cable."

1932.
4 Jan. F. COOTE.
"The work of the Maintenance Staff."
W. DIXON.
"Teleprinters."
J. R. MILNES.
"Secondary Cells."
1 Feb. W. E. GILL.
"Voice Frequency Work."
7 Mar. T. S. SKEET.
"Tuning Iron-cored Inductances. Energy Reflection in Telephone Circuits with special reference to Multiple Way Repeaters."

NORTH WALES CENTRE.

1931.
— E. REDPATH (*Technical Staff, B.B.C.*).
"Short Wave Transmission."
— Capt. N. F. CAVE-BROWNE-CAVE, B.Sc., M.I.E.E. (*Eastern Centre*).
"Characteristics of some Non-Metallic Materials."
— H. P. LLOYD.
"Birmingham Auto Scheme External."
— C. V. LAW.
To be arranged.
— G. H. CARRIER.
"Protons."
— J. S. ELSTON, A.M.I.E.E. (*E.-in-C.O.*).
"Trunk Telephone Re-organisation Plan."

SOUTH WALES CENTRE.

1931.
12 Oct. Visit to Messrs. Burt & Co., Newport, Pole Creosote Yard.
9 Nov. W. DAY, A.M.I.E.E.
"The Philosophy of Engineering."
15 Dec. J. S. ELSTON, A.M.I.E.E. (*E.-in-C.O.*).
"Trunk Telephone Re-organisation Plan."
1932.
11 Jan. R. E. SOPER (*E.-in-C.O.*).
"Special features of Underground Contract Works."
8 Feb. B. LYNN (*E.-in-C.O.*).
"Voice Frequency Key Sending at Automatic Exchanges."
14 Mar. *To be arranged.*

SOUTH MIDLAND CENTRE.

1931.
7 Oct. *To be arranged.*
4 Nov. J. S. ELSTON, A.M.I.E.E. (*E.-in-C.O.*).
"Trunk Telephone Re-organisation Plan."
2 Dec. E. J. S. ROBERTS.
"Unit Maintenance Costs."
1932.
6 Jan. E. CLIFFORD HARRIS.
"Cabling Economics."
3 Feb. R. J. S. GOLD (*E.-in-C.O.*).
"Re-Valuation of the Department's External Line Plant."
2 Mar. H. G. YEATMAN.
"Development."

SOUTH WESTERN CENTRE.

1931.
13 Oct. Major W. M. BATCHELOR, D.S.O., M.C.
Chairman's Address.
10 Nov. W. WARE.
"Radio Station—Portishead."
8 Dec. *To be arranged.*
1932.
12 Jan. J. S. ELSTON, A.M.I.E.E. (*E.-in-C.O.*).
"Trunk Telephone Re-organisation Plan."
9 Feb. *To be arranged.*
8 Mar. S. PRESTON and P. G. TREGLOWN.
"Bristol Auto Transfer."

SCOTLAND EAST CENTRE.

Not yet available.

SCOTLAND WEST CENTRE.

1931.
5 Oct. F. W. TURNER.
"Wayleaves."
2 Nov. A. MCNEILL.
"Ayr Automatic Transfer."
7 Dec. Informal.
1932.
18 Jan. M. BEATTIE.
"Telephones, Past and Present" (Glasgow particularly).
1 Feb. R. MILNE.
"Some remarks on Records."
7 Mar. Informal.

NORTHERN IRELAND CENTRE.

1931.
6 Oct. T. RODGER (*District Manager, Belfast*).
Opening Address.
3 Nov. J. S. ELSTON, A.M.I.E.E. (*E.-in-C.O.*).
"Trunk Telephone Re-organisation Plan."
— Dec. A. S. COLSTON.
"Belfast Special Underground Construction."
1932.
— Feb. A. H. JACQUEST, A.M.I.E.E.
"Frequency—its bearing on Communication Channels and Rentals."
— Mar. F. GALLAGHER.
"Works estimates from the Records standpoint."
— Apr. *To be arranged.*

THE INSTITUTION OF P.O. ELECTRICAL ENGINEERS.

Officers of Colonial and Foreign Telegraph Administrations who are engaged in Electrical Engineering Works may be admitted as Colonial and Foreign Corresponding Members respectively, after application.

Subscription payable annually in advance on 1st April in each year:

Colonial Members	...	...	£1 0 0
Foreign ,,	...	...	£1 10 0

These sums include Annual Subscription to the Journal of P.O. Electrical Engineers and the supply of all Professional Papers issued during the period covered by subscription.

Forms of application for Colonial and Foreign Membership can be obtained on application to

The Secretary,
Institution of P.O.E. Engineers,
G.P.O. (Alder House), E.C.1,

or the undermentioned gentlemen who have kindly agreed to act as representatives of the Institution in their respective countries:—

R. Badenach, Esq., B.Sc. (Melb.),
Chief Engineer's Office,
Postmaster-General's Department,
Treasury Gardens,
Melbourne, C.2,
Australia.

H. C. Brent, Esq.,
District Telegraph Engineer's Office,
Wellington, N.Z.

N. N. Banerjee, Esq., A.M.I.E.E. (Ind.),
Divisional Engineer, Telegraphs,
Calcutta West Division,
8, Wellesley Place,
Calcutta,
India.

A. T. Kingston, Esq., M.B.E., A.M.I.E.E.,
Office of the Chief Engineer,
Telegraphs & Telephones,
C.T.O.,
Colombo,
Ceylon.

A. J. Kellaway, Esq.,
Department of Posts and Telegraphs,
P.O. Box 395,
Pretoria,
South Africa.

E. L. Jephcott, Esq., A.M.I.R.E.,
Chief Engineer's Department,
G.P.O. Box 391,
Salisbury,
South Rhodesia.

ESSAY COMPETITION.

The Council has decided to offer five prizes of two guineas each for the five most meritorious Essays submitted to it by employees of the Engineering Department of the Post Office below the ranks of Inspector and Draughtsmen Class II., and, in addition, to award a limited number of Certificates of Merit.

A candidate who has won a prize shall not be eligible to enter for this competition, but this restriction shall not apply to a candidate who has been awarded a certificate only.

Each competitor may choose any subject relevant to current telegraph or telephone practice. It is thought that the list given below of suitable subjects for Essays, though not exhaustive, will prove of assistance to competitors. The subject need not, however, be chosen from this list, but it must be relevant to current telegraph or telephone practice.—

A Long-distance Conversation.
A Practical Analysis of Characteristic Faults at Automatic Exchanges.
A Short History of Telephony.
A Telephone Man's attitude to the Subscriber.
Advice Note Procedure.
Aerial Cables.
Automatic Private Branch Exchanges.
Automatic Telephony.
Cable Balancing.
Cable Drawing.
Capacity Effects in Telephony—Wired or Wireless.
Carrier Wave Telegraphy and Telephony.
Change Over from an Old to a New Exchange Equipment.
Common Battery Manual Telephone System.
Conveyors—their Installation and Maintenance.
Cord Circuit Repeaters.
Corrosion of Lead Covered Cables.
Departmental Methods of Costing.
Electrical Clocks.
Electric Light and Power Installations.
Emergency Arrangements.
Extension of Large Telephone Exchange Multiples.
Fault Procedure at Automatic and Manual Exchanges.
Fire Alarm Systems.
Insulation.
Internal Combustion Engines.
Jointing.
Lifts—their Instal'ation and Maintenance.
Lineman's Maintenance Load.
Live Wires.
Long Distance Wireless.
Manual versus Automatic.
Methods of increasing Output.
Modern Aspects of Electricity and Magnetism.
Modern Telephone Practice.
Multi-Office Automatic Telephony.
Oscillographs.
Overhead Construction—Precautions to avoid Interference with Working Circuits.
Overhead Line Construction.
Overhead Line Maintenance.
Practical and Theoretical Training.
Precision Testing of Underground Cables.
Preparation of Development Schemes.
Primary Batteries.
Radio Communications—any phase of.
Routine Testing in Automatic Exchanges.
Rural Automatic Exchanges.
Secondary Batteries.
Sound and Hearing.
Specialization—advantages and disadvantages.
Stamping Machines.
Store Keeping.
Subscribers' Switchboards.
Technical Education in Practice.
Telegraph Printing Apparatus.
Telegraph Working with Batteries.
Telephone Buildings.
Telephone Development.
Telephone Fitting.
Telephone Line Construction.
Telephone Repeaters.
Telephone Transmission.
Telephony Considered from a Subscriber's point of view.
Television.
The Construction of a Modern Balanced Cable.
The Economy of the Leclanché Cell.
The Economical Lay-out of Construction Work, etc.
The growth of the Trunk Service.
The Installation of a New Telephone Exchange Equipment.
The Laying of Pipes and Ducts.
The Loading of Telephone Circuits.
The London Trunk Exchange.
The merits of Overhead and Underground Distribution, with particular reference to costs.
The Telephone System of the British Post Office.
The Thermionic Valve.
The Theory of the Accumulator.
The Training of Youths.
The Use of Motor Transport in the Telephone business.
The Value of Private Study.
The Ventilation and Heating of Automatic Exchanges and Repeater Stations.
The Wiring of Large Buildings.
Traffic Recording in Automatic Exchanges.
Trunk and Junction Testing.
Trunking in Automatic Exchanges.
Underground Cables.
Underground Line Construction.
Voice Frequency Signalling Systems.
Wireless. Investigation of Broadcast Interference.

Each Essay must be written on foolscap on one side of the paper only, and must not exceed 5,000 words. A quarter margin to be left on each page. A certificate is required to be furnished by each competitor, at the end of the essay, in the following terms:—

"In forwarding the foregoing essay of.....words, I certify that the work is my own unaided effort both as regards composition and drawing."

Address..... *Signature*.....

Date..... *Rank*.....

The Essays must reach
The Secretary,
The Institution of Post Office Electrical Engineers,
G.P.O. (Alder House), E.C.1,

before the 31st December, 1931.

The Council reserves the right to refrain from awarding the full number of prizes or certificates if, in its opinion, the Essays submitted do not attain a sufficiently high standard.

J. J. McKICHAN,
Secretary.

OUTLINE NOTES ON TELEPHONE TRANSMISSION THEORY.

W. T. PALMER, B.Sc., Wh.Ex., A.M.I.E.E

SECTION 10—*continued.*

(1) Volume Efficiency.

Three principal units have been used to express this factor :—

(*a*) The " natural " attenuation unit.
(*b*) The " mile of standard cable " or M.S.C. unit.
(*c*) The " decibel "—sometimes referred to as the " TU " or " Transmission unit."

The decibel is the unit now used in America and by the British Post Office. The " natural " unit (the neper) is used by most other Continental administrations.

(*a*) *The Natural Attenuation Unit.*—This is known variously as the napier, neper or hyp.

If I_r = received current of a given system
I_s = sent current of the system.

then *if each of these currents is flowing into equal impedances* (as would be the case for a uniform line closed at the receiving end by the characteristic impedance Z_0) we can consider the ratio $I_r : I_s$ to represent the " volume " efficiency of the system. Since in the case of the infinite uniform line the ratio $\frac{I_r}{I_s}$ is of exponential form it has naturally become the practice to write—

$$\frac{I_r}{I_s} = e^{-\gamma l} \quad \text{(See Section equation).}$$

and to base the natural unit of attenuation on this formula.

In general γ is a complex quantity $= \beta + j\alpha$ and it is only necessary to consider the real part β since this alone determines the relative *magnitudes* of the two currents. Hence for scalar values of I_s and I_r :—

$$\frac{I_r}{I_s} = e^{-\beta l}$$

$$i.e., \quad \beta l = \log_e \frac{I_s}{I_r} \fallingdotseq 2.303 \log_{10} \frac{I_s}{I_r} \qquad \text{.....(1)}$$

Thus if $\frac{I_s}{I_r} = e$

then βl = unity, *which defines the neper* as the attenuation of a system with the ratio $I_s : I_r$ equal to $e \fallingdotseq 2.718$.

Example.—If in a uniform line of 50 miles closed by Z_0 the sent current is 20 and the received current is 2 m.A, then the total attenuation is given by equation (1) :—

$$\beta l = \log_e \frac{20}{2} \fallingdotseq 2.3 \text{ nepers.}$$

Since $l = 50$ then it can be written that the *attenuation constant* of the line $= 2.3 \div 50$ $= 0.046$ *neper per mile.*

If P_s and P_r represent the corresponding powers required I_s by and I_r *flowing into equal impedances* Z_0, then—

$$P_s = I_s^2 Z_0 \text{ and } P_r = I_r^2 Z_0$$

$$\therefore \quad \log_e \frac{I_s}{I_r} = \log_e \sqrt{\frac{P_s}{P_r}} = \tfrac{1}{2} \log_e \frac{P_s}{P_r}$$

$\therefore$ Equation (1) becomes : —

$$\beta l = 1.151 \log_{10} \frac{P_s}{P_r} \qquad \text{.....(2)}$$

Example.—If in the foregoing example the currents were flowing into 1000 ohm impedances then—

$P_s = 0.4$ millowatt
$P_r = 0.004$ millowatt

Using equation (2)

$$\beta l = \tfrac{1}{2} \log_e \frac{P_s}{P_r} = \tfrac{1}{2} \log_e \frac{0.4}{0.004}$$

$= 2.3$ nepers as before.

(*b*) *The Mile of Standard Cable (M.S.C.).*—This unit is now rarely used, having been replaced by the decibel. The M.S.C. is approximately one-tenth the magnitude of the neper and is thus of more convenient size for ordinary practical use. The volume efficiency of a line or piece of apparatus is then expressed by stating the number of miles of standard cable which gives the same ratio of received to sent currents. In England the standard mile is

defined as a cable having the following constants:—

$$\left.\begin{array}{l} R = 88 \text{ ohms per mile loop} \\ L = 1 \text{ mH per mile loop} \\ G = 1 \times 10^{-6} \text{ mho per mile loop} \\ C = 0.054\ \mu F \text{ per mile loop} \end{array}\right\} \text{Standard mile.}$$

The attenuation constant of such a mile can be calculated from equation (18) of Section 2, and comes to *0.106 neper* at 800 periods per second. Hence if a cable has a total attenuation length of $\beta l = 2.12$ nepers at 800 p.p.s. then its **S.C.E.** (Standard cable equivalent) is $2.12 \div .106 = 20$ M.S.C.

In general for a cable of S.C.E. = M mls.:—

$$\beta l = \log_e \frac{I_s}{I_r} = 0.106\ M$$

$$i.e.,\ \beta l \fallingdotseq \frac{1}{10} M$$

In other words, the M.S.C. unit (at 800 p.p.s.) is nearly one-tenth the neper or natural unit. From equation (1), M (M.S.C.) = $(2.303 \div 0.106) \log_{10} \frac{I_s}{I_r}$

$$\therefore \quad M\ (M.S.C.) = 21.72 \log_{10} \frac{I_s}{I_r} \quad \ldots\ldots\ldots\ldots (3)$$

If P_s and P_r represent the sent and received powers respectively sent into equal impedances then as in pp. (*a*) it can be shown that—

$$M\ (M.S.C.) = 10.86 \log_{10} \frac{P_s}{P_r} \quad \ldots\ldots\ldots\ldots (4)$$

The American Standard Cable (800 cycle-mile) has

$$R = 88 \text{ ohm per mile loop}$$
$$C = 0.054\ \mu F \text{ per mile loop}$$

and L and G are neglected. Hence the attenuation constant at $f = 800$ p.p.s. is *0.109 neper* (as compared with the English Standard cable value of 0.106. The difference is chiefly due to the absence of inductance in the American Standard).

(*c*) *The Decibed (db) or Transmission Unit (TU).*—It is clear that the attenuation constant of the M.S.C. is dependent on frequency,—See equation 18, Section 2, and hence the standard cable equivalent of a system will be

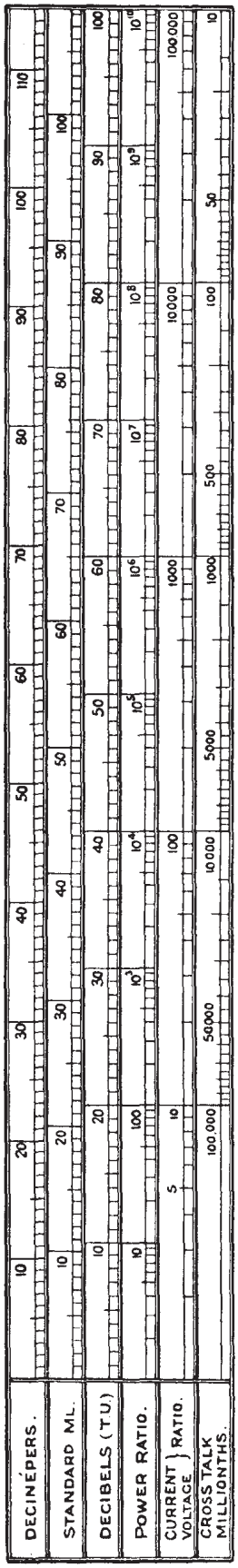


FIG. 28.—A SCALE GIVING THE RELATIONSHIP BETWEEN THE UNITS GENERALLY USED IN TELEPHONE ENGINEERING.

CONVERSION TABLE.

Decibel.	M.S.C. (Miles of Standard Cable).	Neper.
1.0000	1.0846	0.11513
0.9221	1.000	0.10616
8.686	9.420	1.00000

different for different frequencies. Due to this variation, and because 800 p.p.s. as a standard mean speech frequency is not universally accepted, there has been adopted a distortionless transmission unit (TU) referred to as the *decibel* and is defined so that (using the nomenclature of pps. (*a*) and (*b*)) the number of decibels (N) to which a system is equivalent is given by—

$$N = 10 \log_{10} \frac{P_s}{P_r} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

The function $\log_{10} \frac{P_s}{P_r}$ is said to represent the volume efficiency of the system in bels.

Comparing (4) with (5):—

$$\log_{10} \frac{P_s}{P_r} = \frac{M}{10.86} = \frac{N}{10}$$

i.e., 1 M.S.C. = .922 db.

Comparing (1) with (5):—

1 neper = 8.686 db.

i.e., the decibel is very approximately of the same magnitude as the M.S.C. at 800 p.p.s. and nearly one-tenth the size of the neper.

Hence the following advantages are claimed for the decibel—

- (α) Of convenient size and is a fundamental unit.
- (β) Independent of frequency.
- (γ) As simple a physical significance as the M.S.C. and can be easily constructed.
- (δ) Common log tables only required for calculation purposes.

From equation (5) the decibel is defined as the attenuation of a system with the ratio $I_s : I_r$ equal to $10^{0.05} \fallingdotseq 1.12$.

See Fig. **28**, which shows a useful conversion Scale and has been reduced to a size suitable for fixing on the back of an ordinary 10″ slide rule.

Example.—From the foregoing notes it will be seen that the transmission equivalents required in Example 2 in Section 9 are found as follows:

Before loading calculate β in nepers from equation (18) of Section 2, but putting L=0.001. Then the transmission equivalent is (8.686 × β) in decibels.

β will be found to be 0.107 nepers
= 0.93 db. per ml., giving a total equivalent of 50 × 0.93 db. = *46.5 db.*

After loading, the attenuation, β in nepers, can be found from equation (18), Section 2, and is equivalent to

= 8.696 × 0.02 db. per ml.
= 0.17 db. per ml., giving a total equivalent of 50 × 0.17 db. = *8.5 db.*

(*a*) Articulation Efficiency.

Articulation tests were proposed by Campbell in 1910, but it is only during the last few years that the technique of making such tests has been sufficiently well developed to ensure accuracy of results.

The tests are carried out by trained speakers reading aloud, into the sending end of the system, a number of groups of meaningless monosyllables and the percentage of these sounds correctly received, by trained listeners at the receiving end, is computed.

In the special cases of standard systems (using reference transmitters, reference artificial lines and receivers—See Section 11 of Notes) used in the laboratory for investigating the articulation may reach as high as 98%, but in the average system using ordinary commercial apparatus it is much lower, being of the order of 60% to 70%.

To-day, when any new piece of telephone apparatus is developed, it is usual during testing to include both volume and articulation tests and to determine the suitability of the new apparatus by a comparative study of the results of these tests.

Recently, further tests of the "*intelligibility of words*" and "*intelligibility of phrases*" have been made from which the "intelligibility" of the system may be estimated.

A relation between articulation efficiency and intelligibility is indicated in Fig. **29**, taken from a paper by B. S. Cohen in the J.I.E.E., Vol. 66, p. 169.

(Section 10 to be continued.)

References for Section 10:—

Journal I.E.E., Vol. 66, p. 165.—"Apparatus Standards of Telephonic Transmission," by B. S. Cohen.

Journal of the Franklin Institute, June, 1922.—"The Nature of Speech and its Interpretation," by Harvey Fletcher.

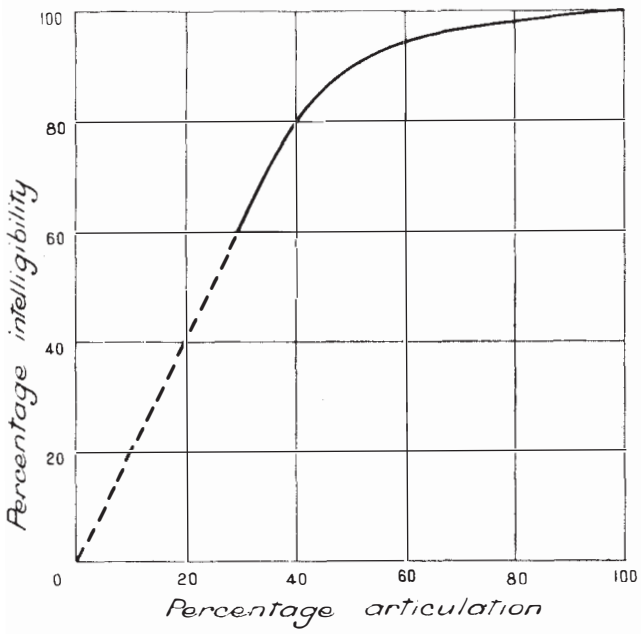


FIG. 29.

Elek. Nachrichten, Vol. 4, p. 184.—" Articulation Tests in Telephone Transmission Systems," by H. F. Mayer.

Electrical Communication, Jan., 1929.—" A Theoretical Study of Articulation and Intelligibility of a Telephone Circuit," by John Collard.

" Speech and Hearing," by H. Fletcher. Published by D. Van Nostrund Co. Inc.

NOTES FOR ADDITION TO SECTION 1 :—

(*h*) Solution of Network Problems.

For this purpose there are three main methods of attack, viz. :—

(1) **By means of Kirchoff's Laws** and use of Maxwell's cyclic currents to obtain a number of simultaneous equations which are solved by the use of Determinants. This is probably the best known method and is not dealt with more fully here. References are given at the end which will be found useful.

(2) **By the "Network" Theorem** or Star-Mesh Transformation Theorem. This theorem states :—

In any network a star of n rays, OA = *a,* OB = *b,* OC = *c* . . . . ON = *n* (See Fig. **30** (*a*)) *may be replaced by a mesh* (Fig. **30** (*b*)) *of* $\frac{1}{2}$ *n* (*n* − 1) *conductors joining every pair of points.* A, B, C . . . N(*O being eliminated*) *without affecting the rest of the network: and then for conductance operators:—*

$$AB = \frac{ab}{\Sigma a}, \quad BC = \frac{bc}{\Sigma a}, \quad CD = \frac{cd}{\Sigma a}, \text{ etc.} \quad \ldots\ldots(1)$$

where $\Sigma a = a + b + c + \ldots n$

For impedance operators:—

$$AB = ab\sum\frac{1}{a}, \quad BC = bc\sum\frac{1}{a}, \quad CD = cd\sum\frac{1}{a} \quad \text{etc.} \ldots\ldots\ldots(2)$$

where $\sum\frac{1}{a} = \frac{1}{a} + \frac{1}{b} + \frac{1}{c} + \ldots \frac{1}{n}$

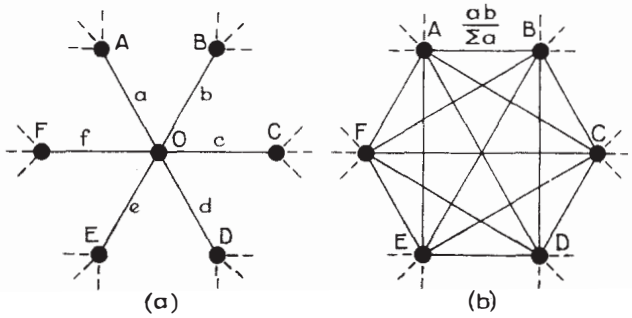


FIG. 30.

Note.—(*α*) In general the number of mesh conductors is greater than the number of rays in the corresponding star and hence the general theorem is not reciprocal (*i.e.*, no mesh in which the members are arbitrary can be converted into a star). *One exception,* however, arises when *n* = 3 in which case the number of mesh conductors equals the number of rays and a *triangular mesh* can always be replaced by an equivalent star. (Fig. **32**).

(*β*) Another particular case of the general theorem arises when *n* = 2 which represents two conductors in series (Fig. **31**), wherein the 2-ray star OA, OB transforms to $AB = \frac{ab}{a+b}$

Using impedance operators—

$$AB = ab\left(\frac{1}{a} + \frac{1}{b}\right) = a + b.$$

Except in this simple case the impedance operators are not so convenient to use on account of the frequent addition of conductors in parallel and in the following example conductances or admittances are employed :—

Example.—To find the effect on the balance of a Wheatstone bridge of earth admittances located at the four corners of the bridge A, B, C, D. (Fig. **33** (*a*)).

Applying the transformation theorem to the 4-ray star AE, BE, CE, DE, the new condition for balance can be written down directly. (Fig. **33** (*b*)).

$$\left(w+\frac{ac}{\Delta}\right)\left(y+\frac{bd}{\Delta}\right)=\left(x+\frac{bc}{\Delta}\right)\left(z+\frac{ad}{\Delta}\right)\ldots\ldots(1)$$

Where $D = a + b + c + d$.

Fig. 31.

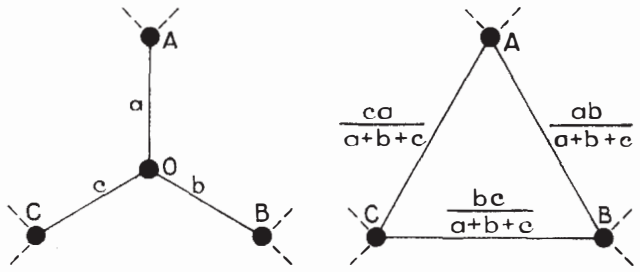


Fig. 32.

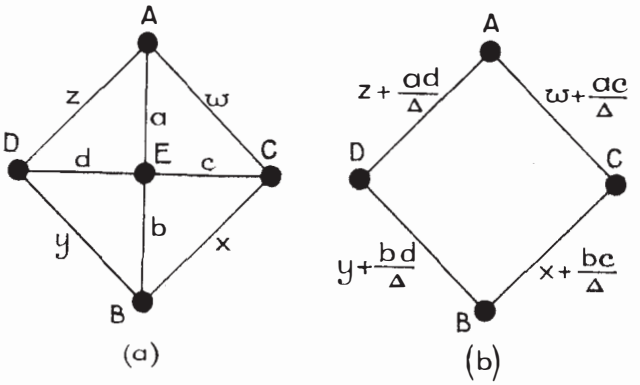


Fig. 33.

The admittances $\frac{cd}{\Delta}$ and $\frac{ab}{\Delta}$ which would appear across CD and AB respectively by the transformation are not shown as they appear across either the source or the detector and do not affect the condition for balance given in equation (1).

(3) **By Thevenin's Theorem** certain classes of network can be very quickly solved. This theorem states :—

In any system of arbitrary linear conductors (in which the current in every branch is proportional to the impressed voltage) the current in any branch is that which would result should an E.M.F., equal to the p.d. which would appear across the break were the branch opened, be introduced into the branch and all other E.M.F's be removed.

In other words, the theorem can be stated :—

The current in any branch, z, of a network may be determined by replacing the remainder of the network by a generator whose E.M.F. is V and internal impedance Z where V and Z are the values measured at the terminals of z when that branch is opened, i.e., the generator is an open circuit. The current in the branch z is then given by $\frac{V}{Z+z}$.

An example of the use of this theorem occurs in Section 10, pp. (*c*) and the following example is given here for comparison of this method (3) with method (1) :—

Example.—To find an expression for the current in the galvanometer branch of a Wheatstone bridge and the condition for balance.

Using Method (1).—By applying Kirchoff's Laws and Maxwell's cyclic currents (Figs. **34** and **35**) the required current x can be found from the equations :—

$$\left.\begin{aligned}(a+b+g)(x+y)-gy-bz&=0\\(f+g+d)y-g(x+y)-dz&=0\\(b+d+h)z-b(x+y)-dy&=e\end{aligned}\right\}\qquad(1)$$

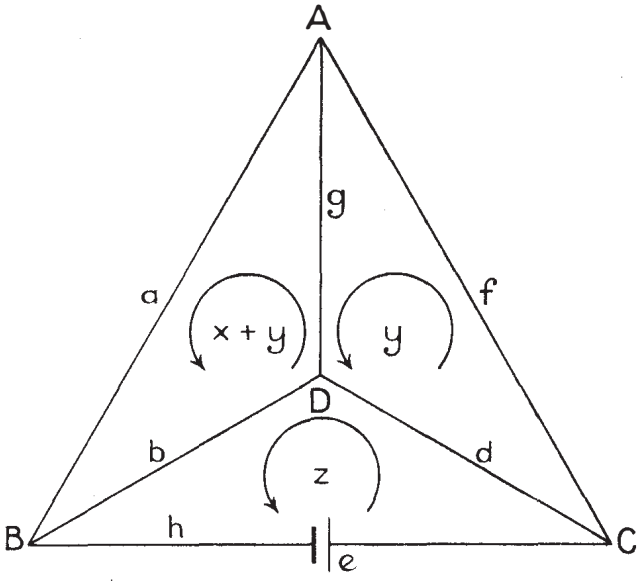


FIG. 34.

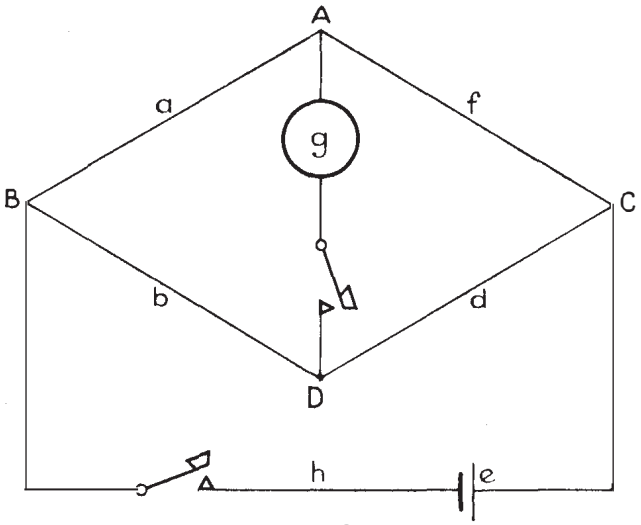


FIG. 35.

By rearrangement :—

$$\left.\begin{aligned} (a+b+g)x + (a+b)y - bz &= 0 \\ -gx + (d+f)y - dz &= 0 \\ -bx - (b+d)y + (b+d+h)z &= e \end{aligned}\right\} \quad (2)$$

Hence by the Theory of Determinants :—

$$x = \frac{\begin{vmatrix} 0 & (a+b) & -b \\ 0 & (d+f) & -d \\ e & -(b+d) & (b+d+h) \end{vmatrix}}{\begin{vmatrix} (a+b+g) & (a+b) & -b \\ -g & (d+f) & -d \\ -b & (b+d) & (b+d+h) \end{vmatrix}}$$

$$\therefore\ x = e\,\frac{\begin{vmatrix} (d+f) & -d \\ (a+b) & -b \end{vmatrix}}{\Delta} = \frac{e(bf-ad)}{\Delta}$$

For a balance $x = 0$

$\therefore$ $bf = ad$ *is the required condition.*

Using Method (3).

Let *p.d.* between B and C be E when the galvanometer branch is opened (Fig. **34**).

Then *p.d.* between B and A is $\frac{a}{a+f}$. E

and ,, ,, B and D is $\frac{b}{b+d}$. E

$\therefore$ *p.d.* across the open salvo branch AD is

$$E\left(\frac{b}{b+d} - \frac{a}{a+f}\right)$$

If R = external resistance to an E.M.F. in the galvanometer branch then *by Thevenin's Theorem* the current, x, in the branch when the circuit is closed is :—

$$x = \frac{E}{g+R}\left(\frac{b}{b+d} - \frac{a}{a+f}\right)$$

i.e., $x = \frac{E}{(g+R)(b+d)(a+f)}(bf-ad)$

$\therefore$ *The condition for balance* ($x = 0$) *is* $bf = ad$.

Note.—Fig **25A** below refers to Section 9 of the last issue.

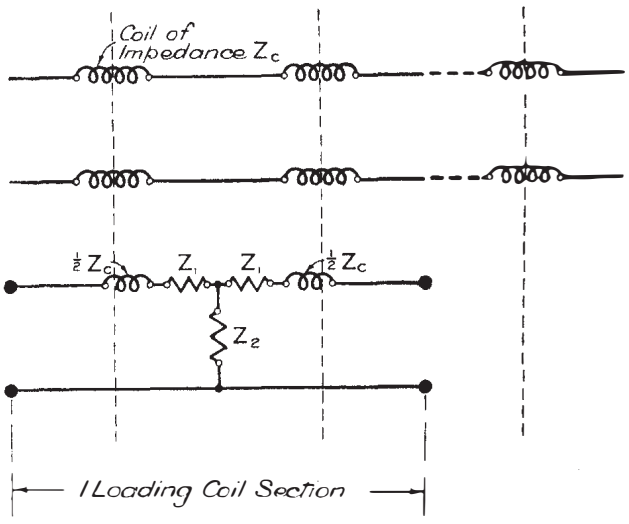


FIG. **25A.**

Useful References for the foregoing Additional Notes to Section 1.

" Determinants for Electrical Engineers," by H. P. Few. Published by S. Rentell & Co.

" A New Network Theorem," by A. Rosen. J.I.E.E., Vol. 62, p. 916.

" Direct Capacity Measurement," by G. A. Campbell. Bell System Tech. Journal, July, 1922.

" The Equivalence of Triangles and Three Pointed Stars in Conducting Networks," by A. E. Kennelly. Elec. World, 1899, Vol. 34, p. 413.

Discussion of " New Network Theorem," by A. Morris. J.I.E.E., p. 303, Vol. 63.

" A Principle Governing the Distribution of Current in Systems of Linear Conductors," by Dr. F. Wenner. Proc. Phys. Soc., p. 124, Vol. 30.

" Transmission Circuits for Telephonic Communication " (p. 79), by K. S. Johnson. Published by Library Press, Ltd., London.

[*This series of papers when completed will be published in book form.—Eds. P.O.E.E. Jnl.*]

STAFF CHANGES.

POST OFFICE ENGINEERING DEPARTMENT.

PROMOTIONS.

Name.	From	To	Date.
Hudson, A.	Senior Staff Officer, Stores Dept.	Staff Engineer, E.-in-C.O.	3-6-31
Burns, W. C.	Staff Officer, Stores Dept.	Motor Transport Officer, Cl. I., E.-in-C.O.	1-7-31
Strachan, L. D.	Staff Officer, Stores Dept.	Motor Transport Officer, Cl. II., E.-in-C.O.	1-7-31
Benzies, A.	Staff Officer, Stores Dept.	Motor Transport Officer, Cl. II., E.-in-C.O.	1-7-31
Robinson, R. T.	Assistant Engineer, E.-in-C.O.	Motor Transport Officer, Cl. II., E.-in-C.O.	1-7-31
Wood, P. T.	Assistant Staff Engineer, E.-in-C.O.	Suptg. Engineer, S. West District.	1-11-31
Kitchen, H.	Assistant Staff Engineer, E.-in-C.O.	Suptg. Engineer, Scot. East District.	23-8-31
Smart, E. V.	Executive Engineer, London District.	Assistant Suptg. Engineer, London. District.	1-7-31
Leigh, C.	Executive Engineer, E.-in-C.O.	Assistant Staff Engineer, E.-in-C.O.	5-11-31
Johnson, A. S. A.	Executive Engineer, E.-in-C.O.	Assistant Staff Engineer, E.-in-C.O.	1-11-31
Gear, W. J.	Assistant Engineer, London District.	Executive Engineer, London District.	1-7-31
Ellson, F. A.	Assistant Engineer, E.-in-C.O.	Executive Engineer, E.-in-C.O.	1-11-31
White, H. W.	Assistant Engineer, E.-in-C.O.	Executive Engineer, London District.	1-11-31
Salmon, J. B.	Assistant Engineer, N. Wales District.	Executive Engineer, E. District.	1-10-31
Morrell, E. J.	Assistant Engineer, E.-in-C.O.	Executive Engineer, E.-in-C.O.	5-11-31
Hay, P. G.	Assistant Engineer, S. East District.	Executive Engineer, S. East District.	1-8-31
West, A. S.	Chief Inspector, E.-in-C.O.	Assistant Engineer, S. West District.	16-7-31
Nichols, E. H.	Chief Inspector, London District.	Assistant Engineer, London District.	1-11-31
Evans, E. C.	Chief Inspector, London District.	Assistant Engineer, London District.	1-8-31
Eaton, H.	Chief Inspector, N. West District.	Assistant Engineer, S. Lancs. District.	To be fixed later.
Kilgour, A.	Chief Inspector, Scot. West District.	Assistant Engineer, Scot. West District.	To be fixed later.
Mitchell, C. A.	Chief Inspector, E. District.	Assistant Engineer, S. East District.	To be fixed later.
Beazer, F. C.	Chief Inspector, London District.	Assistant Engineer, London District.	To be fixed later.
Law, C. V.	Chief Inspector, N. Wales District.	Assistant Engineer, N. Wales District.	To be fixed later.
McIntosh, J.	Chief Inspector, Scot. East District.	Assistant Engineer, Scot. East District.	To be fixed later.
Vernon, R. J.	Chief Inspector, E.-in-C.O.	Assistant Engineer, E.-in-C.O.	To be fixed later.
Mayman, A. C.	Chief Inspector, E.-in-C.O.	Assistant Engineer, E.-in-C.O.	To be fixed later.
Rathbone, W. F.	Inspector, S.E. District.	Chief Inspector, N. Mid. District.	To be fixed later.
Allsop, E.	Inspector, N.E. District.	Chief Inspector (Allocation to be fixed later).	To be fixed later.

Name.	From	To	Date
Harper, H.	Inspector, Scot. East District.	Chief Inspector, Scot. East District.	To be fixed later.
Sutter, A. S.	Inspector, Scot. West District.	Chief Inspector, Scot. West District.	To be fixed later.
White, J. A.	Inspector, S.E. District.	Chief Inspector, E. District.	To be fixed later.
McLennan, M.	Inspector, Scot. East District.	Chief Inspector, Scot. West District.	To be fixed later.
Scott, W. F.	Inspector, London District.	Chief Inspector, London District.	To be fixed later.
Lowe, J.	Inspector, N. District.	Chief Inspector (Allocation to be fixed later).	To be fixed later.
Langford, L. C.	Inspector, London District.	Chief Inspector, London District.	To be fixed later.
Baily, W. H.	Inspector, London District.	Chief Inspector, London District.	To be fixed later.
Whittaker, A. W.	Inspector, London District.	Chief Inspector, London District.	To be fixed later.
Scarborough, W. H.	Inspector, E.-in-C.O.	Chief Inspector, E.-in-C.O.	27-5-30
Bevis, W. F.	Repeater Officer, Cl. II., E. District.	Chief Inspector, E.-in-C.O.	5-9-30
Peirce, J. G.	Unest. Skilled Workman, Testing Branch.	Inspector, Testing Branch.	To be fixed later.
Sumner, J.	Skilled Workman, Cl. I., S. Lancs. District.	Inspector, S. Lancs District.	To be fixed later.
Deamon, T. E.	Skilled Workman, Cl. I., N. Mid. District.	Inspector, N. Mid. District.	To be fixed later.
Williams, G. A.	Unest. Skilled Workman, S. Lancs. District.	Inspector, S. Lancs District.	To be fixed later.
Nichols, J.	Skilled Workman, Cl. I., S. Lancs. District.	Inspector, S. Lancs District.	To be fixed later.
Deighton, C. F.	Skilled Workman, Cl. I., Northern District.	Inspector, N. District.	To be fixed later.
Milwood, W. E.	Skilled Workmen, Cl. I., S. East District.	Inspectors, S. East District.	To be fixed later.
White, W.			
Strange, A.			
Robins, R. E.	Skilled Workmen, Cl. I., S. Mid. District.	Inspectors, S. Mid. District.	To be fixed later.
Sawyer, E. C.			
Charlish, C. R.			
Sanford, A.			
Shrimpton, W. H.			
Read, H.			
Mower, G.	Skilled Workmen, Cl. I., London District.	Inspectors, London District.	To be fixed later.
Davis, A. H.			
Norman, W. H. B. D.			
Allison, A. J.			
Beaven, J. H.			
Adams, H. G.			
Pyman, F. A. M.			
Brandum, W. H.			
Casey, E. S.	Skilled Workman, Cl. II., London District.		
Scott, D. W. R.	Skilled Workmen, Cl. I., S. West District.	Inspectors, S. West District.	To be fixed later.
Jenkinson, T.			
Baker, J.	Skilled Workman, Cl. I.,	Inspector, S. Wales District.	To be fixed later.
Tolhurst, S.	Skilled Workmen, Cl. I., Testing Branch.	Inspectors, Testing Branch.	To be fixed later.
Crofts, A. A.			
Rockall, A. G.			

DEATH.

Name.	Rank.	District.	Date.
Holland, A. E.	Second Officer.	H.M.T.S. "Monarch."	23-7-31

TRANSFERS.

Name.	Rank.	From	To	Date.
Brocklesby, C.	Assistant Suptg. Engineer	N.E. Dist.	N.W. Dist.	1-9-31
Gunston, J. A.	Assistant Engineer.	Scot. E. Dist.	London Dist.	23-8-31

RETIREMENTS.

Name.	Rank.	District.	Date.
Taylor, J. D.	Superintending Engineer.	Scot. East.	15-8-31
Upton, S.	Assistant Suptg. Engineer.	N. West.	31-8-31
Sharpley, A. J.	Executive Engineer.	Eastern.	30-9-31
Eames, E. J.	Executive Engineer.	S. East.	31-7-31
Lockhart, J.	Assistant Engineer.	E.-in-C.O.	31-7-31
Hall, F. M.	Assistant Engineer.	London.	31-7-31
Phillips, A. C.	Assistant Engineer.	S. West.	30-6-31
Paterson, J. S.	Assistant Engineer.	E.-in-C.O.	30-6-31
Bytheway, P. C.	2nd Cl. Engineer.	Scot. West.	1-9-31
Gardner, J. R.	Chief Inspector.	E.-in-C.O.	30-4-31
Macfarlane, A. S. R.	Chief Inspector.	London.	31-5-31
Kennedy, H.	Inspector.	Scot. West.	30-4-31
Earp, E.	Inspector.	N. Mid.	31-7-31
Bishop, F.	Inspector.	S. Lancs.	20-6-31
Elleby, T. H.	Inspector.	S. Wa.	18-6-31
Westmacott, P.	Inspector.	London.	23-7-31
Clatworthy, F. H.	Inspector.	Testing Branch.	2-9-31
Legg, G. E.	Inspector.	E.-in-C.O.	15-7-31
Bullimore, G.	Inspector.	London.	31-5-31

CLERICAL ESTABLISHMENT.

RETIREMENTS.

Name.	Rank.	District.	Date.
Larner, R. H.	Higher Clerical Officer.	London.	31-7-31
Adams, J. W. T.	Higher Clerical Officer.	S. West.	31-7-31
Morrison, G. E. N.	Higher Clerical Officer.	Scot. West.	1-7-31
Cross, W. H.	Higher Clerical Officer.	N. Mid.	31-7-31
Harmsworth, W. H.	Higher Clerical Officer.	S. East.	25-6-31
Brown, C.	Higher Clerical Officer.	S. West.	31-7-31
Hemming, J. G.	Higher Clerical Officer.	N. East.	11-9-31
Smith, J. R.	Higher Clerical Officer.	Eastern.	24-9-31
Cole, G. G.	Executive Officer.	London.	30-9-31

TRANSFERRED.

Name.	Rank.	From	To	Date.
Williams, J. T.	Higher Clerical Officer.	S. Mid. District.	S. East District.	28-6-31
Wilson, E.	Higher Clerical Officer.	Eastern District.	S. Mid. District.	4-8-31

PROMOTIONS.

Name.	From	To	Date.
Scott, W. H.	Clerical Officer, London District.	Higher Clerical Officer, London District.	13-6-31
Francis, H. J. B.	Clerical Officer, London District.	Higher Clerical Officer, London District.	1-7-31
Smerdon, J.	Clerical Officer, London District.	Higher Clerical Officer, London District.	1-8-31
Jones, F. E.	Clerical Officer, S. West District.	Higher Clerical Officer, S. West District.	1-8-31
Calderwood, R. H.	Clerical Officer, Scot. West. District.	Higher Clerical Officer, Scot. West District.	2-7-31
Clements, G. T.	Clerical Officer, N. Mid. District.	Higher Clerical Officer, N. Mid. District.	1-8-31
Hinks, G. W.	Clerical Officer, N. Mid. District.	Higher Clerical Officer, Eastern District.	4-8-31
Ardis, J.	Clerical Officer, Ireland N.	Higher Clerical Officer, S. West District.	1-8-31
Fryer, G. Y.	Clerical Officer, N. East District.	Higher Clerical Officer, Eastern District.	9-8-31

BOARD OF EDITORS.

B. O. ANSON, M.I.E.E., Chairman.

P. J. RIDD, M.I.E.E.

H. KITCHEN, M.I.E.E.

A. J. GILL, B.Sc., M.I.E.E., M.I.R.E.

J. D. BOULTON.

J. T. KELLY.

W. CRUICKSHANK, M.I.E.E., Managing Editor.

J. J. MCKICHAN, O.B.E., A.M.I.E.E., Assistant Editor.

COMMUNICATIONS.

All Remittances and Communications should be addressed to the MANAGING EDITOR, P.O.E.E. JOURNAL, Engineer-in-Chief's Office, Alder House, London, E.C.1.

Binding covers and copies of the Contents for Vol. 3 to 23 are available, and may be obtained from the local agents for 1*s.* 6*d.* and 3*d.* respectively. Subscribers can have their copies of Vol. 23 bound, with index included, at a cost of 3*s.*, by sending the JOURNALS to the local agents. Orders for bindings, Vols. 1—19, should indicate whether the original binding with black lettering, or the latter pattern in gold, is required. Covers with gold lettering will be the only type stocked from Vol. 20 onwards.

The price of the JOURNAL is 1*s.* (1*s.* 3*d.* post free) per copy, or 5*s.* per annum, post free. All back numbers 2*s.* each.

THE
Post Office Electrical Engineers' Journal

SPEED OF SIGNAL TRANSMISSION OVER CARRIER TELEGRAPH CHANNELS.

A SERIES of very interesting tests were carried out on 21-6-31, by the Postmaster-General's Department, over the carrier telegraph systems which have been installed during the last few years in Australia. These tests had for their object the determination of the speed at which telegraph signals are transmitted over carrier telegraph channels.

Three carrier telegraph systems are now in use, *i.e.* :—

(i) Perth to Adelaide—16 uni-directional channels
(ii) Adelaide to Melbourne—12 uni-directional channels, and
(iii) Melbourne to Sydney—12 uni-directional channels.

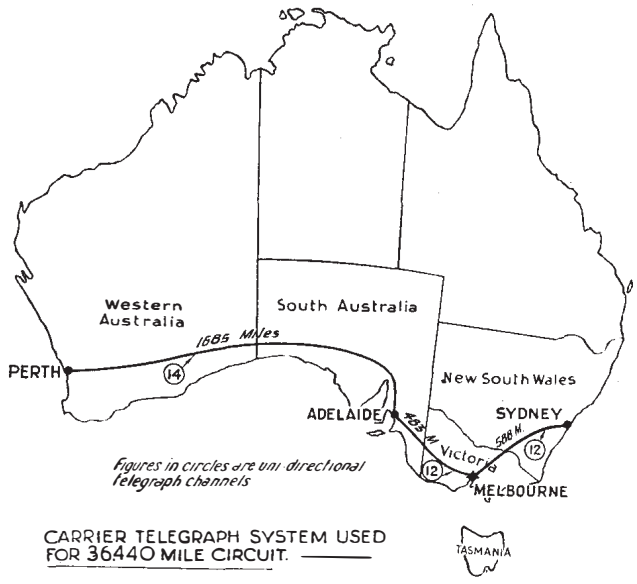


FIG. 1.

All of these channels were linked together for the test, with the exception of two between Perth and Adelaide, which were in use for urgent business. Fig. **1** shows the geographical location of the system, the number of channels used for the test, and the route lengths of each system.

A total of thirty-eight channels were linked together to obtain a telegraph circuit 36,440 miles in length, with both sending and receiving terminals located in the Central Telegraph Office, Melbourne.

The time taken by telegraph signals to traverse the circuit was determined by means of a Westinghouse 3-element oscillograph in the Research Laboratory of the Central Administration of the Department, which is located a short distance away from the Central Telegraph Office. The connections from the sending and receiving apparatus at the Central Telegraph Office to the carrier channels were made through elements of the oscillograph. The arrangement of measuring apparatus, carrier channels, etc., is illustrated in Fig. **2**. The third element of the oscillograph was connected to a 100/cycle/sec. timing wave.

The oscillograms obtained from the test gave the

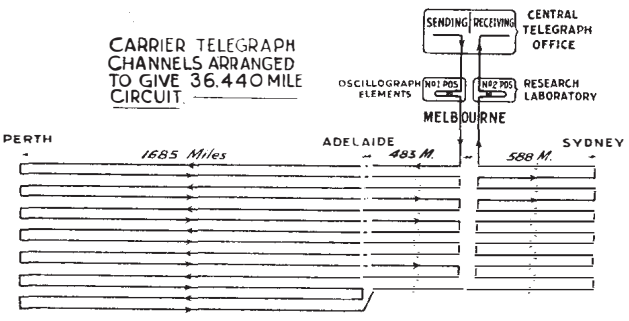


FIG. 3.

time delay, as measured for a number of independent signals, as lying between 0.706 and 0.712 seconds. The average may be taken as 0.71 seconds. This represents the time taken for a signal to traverse the whole 36,440 miles of circuit used, from the time the tongue of the transmitting relay left the spacing contact to the corresponding instant for the receiving relay.

Fig. **3** is a copy of one of the oscillograms obtained from the test. The average time delay of 0.71 seconds, measured from the oscillograms, gives an average speed of transmission over the circuit of

seconds for the thirty-eight channels. The value of 0.0082 seconds was derived from tests on terminal apparatus which gave a delay of 10 to 11 milliseconds at 3,300 cycles/sec. and 5.5 milliseconds at 10,000 cycles/sec. The mean of these two figures, *i.e.*, 8.2 milliseconds, was taken as most nearly representing the actual condition obtaining during the test on the long circuit, as the thirty-eight channels of which it was made up operated at frequencies between 3,300 cycles and 10,000 cycles/sec.

An estimate of 0.358 seconds was also made of the delay due to time of signal travel over the line

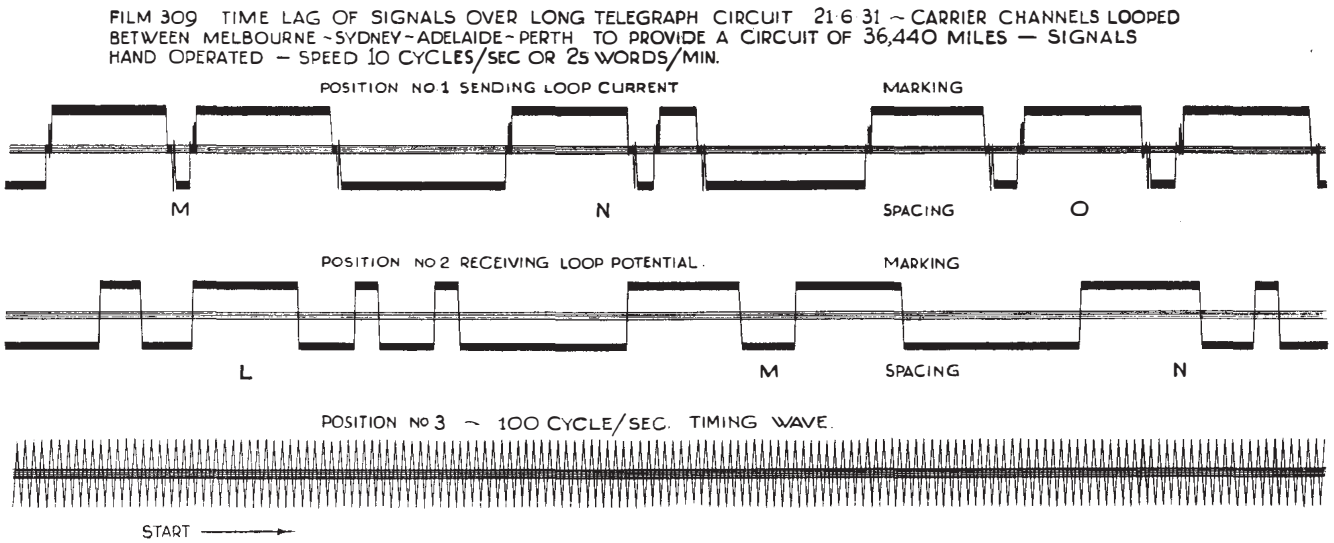

FILM 309 TIME LAG OF SIGNALS OVER LONG TELEGRAPH CIRCUIT 21·6 31 ~ CARRIER CHANNELS LOOPED BETWEEN MELBOURNE ~ SYDNEY ~ ADELAIDE ~ PERTH TO PROVIDE A CIRCUIT OF 36,440 MILES — SIGNALS HAND OPERATED — SPEED 10 CYCLES/SEC OR 25 WORDS/MIN.
POSITION NO 1 SENDING LOOP CURRENT
MARKING
M
N
SPACING
O
POSITION NO 2 RECEIVING LOOP POTENTIAL
MARKING
L
M
SPACING
N
POSITION NO 3 ~ 100 CYCLE/SEC. TIMING WAVE.
START

Fig. **2.**

51,300 miles/sec. The delay is due partly to the time taken for the signal to travel over the line, and through the various carrier repeaters, and partly to delay introduced by terminal apparatus associated with each carrier channel. This latter delay is made up principally of—

(i) Lag in sending and receiving relays due to their inductance, and to the travel time of the relay tongues.

(ii) Time taken by the carrier wave to build up to a steady state in the tuned circuits.

As there were, in all, thirty-eight carrier channels linked together with a total of seventy-six sending and receiving relays, and seventy-six sending and receiving tuned circuits, the time delay for apparatus forms an appreciable proportion of the total of 0.71 seconds. Previous measurements had indicated that the delay per channel, due to apparatus, amounted to 0.0082 seconds, giving a total of 0.312

and through repeaters. This figure was based on a delay of approximately 5.75 milliseconds for the distance from Melbourne to Sydney (588 miles), determined by previous tests.

The estimated delay over the 36,440 mile circuit was, therefore, 0.312 + 0.358 seconds, a total of 0.67 seconds. This estimate of 0.67 seconds compares fairly well with the actual time delay as measured, *i.e.*, 0.71 seconds, especially when allowance is made for the fact that in applying the figure of 5.75 milliseconds to this circuit, a number of general assumptions had to be made.

The tests disclosed that it was possible to transmit messages at up to 30 words per minute either manually or with a Wheatstone transmitter and receiver.

[*A full description of this carrier system, which was manufactured in England by the Standard Telephones and Cables Ltd., will appear in the April issue of this Journal.—Eds. P.O.E.E. Journal.*]

WHITEHALL AUTOMATIC EXCHANGE.

THIS Director Exchange was opened on the 3rd October, 1931, and serves, as its name implies, an area which includes not only the Royal Household, but also the Houses of Parliament and the Chief Government Offices of the Empire. The number of working lines transferred from existing Exchanges (Whitehall, Gerrard and Regent Manual) at the date of the opening was 2,288, and this number will be more than doubled in the near future by further transfers.

The equipment consists of :—

7920 Subscribers' Preselectors.
2125 Final Selectors (including Test and Trunk Offering).
1080 First Code Selectors.
4000 Other Selectors.
191 Directors.
50 Coders.
42 Four digit Senders.
1330 Junction Relay Sets.

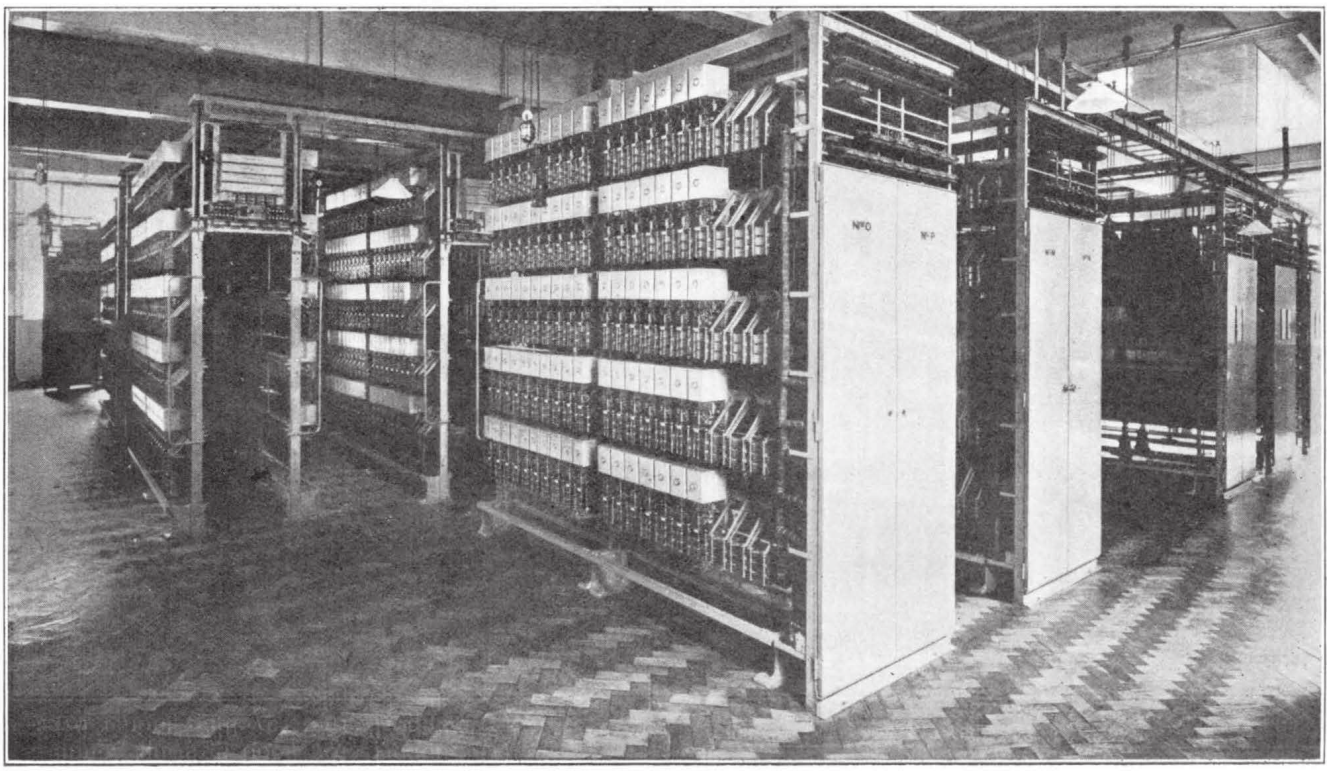


FIG. 1.—WHITEHALL EXCHANGE. NUMERICAL SELECTOR RACKS.

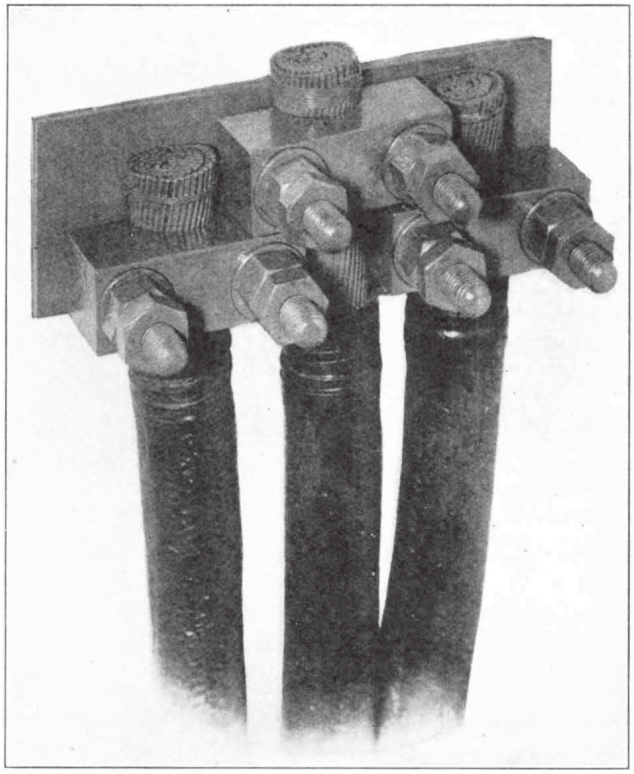


FIG. 2.—POWER CABLE TERMINATIONS.

FIG. 3.—FRONT OF WHITEHALL EXCHANGE.

The special nature of the subscribers in the area is reflected in the details of the Final Selectors, of which there are 559 for Private Branch Exchanges with groups of more than 20 lines, but none of the ordinary or regular type for single subscribers' lines.

All the Code and Numerical Selectors are of the 200 Outlet or 20 Contact per level type and an unusually large proportion of spare banks is fitted to enable additional Selectors to be added rapidly in case of necessity. Fig. 1 depicts a portion of the Numerical Selector Racks.

The equipment was manufactured and installed by Messrs. Siemens Brothers and is of their standard type in accordance with Post Office specification. Numerous deails of such equipment have been given in articles in this Journal describing the nine previous Director Exchanges installed by the same Contractor.

One novel feature of interest is to be found in the method adopted for terminating the cables between the batteries and the power board and the distribution fuse boards. Soldered connections are dispensed with entirely at the cable terminals, the insulation being stripped from the conductors for a length of about six inches and the connections made by clamping the bare copper conductors to the bus bars by bolts and blocks; the extreme ends of the conductors

FIG. 4.—WHITEHALL EXCHANGE. NELL GWYNN'S STAIRCASE.

are bound by tinned copper wire to prevent the splaying of the wires under pressure. The complete connection is painted with red or blue paint. A typical connecting point is illustrated in Fig. **2**.

The building, which occupies two sides of a square known as Craig's Court, is designed to accommodate two 10,000 line Director Exchanges, and the contract for the erection of the second Main Frame has already been placed.

The front of the building, illustrated in Fig. **3**, previously formed part of Harrington House, and this portion, together with the main staircase of the old house, has been scheduled and carefully preserved as a "Historical monument."

Harrington House was probably built shortly before the year 1700 and Mr. Stratton of H.M. Office of Works has given it as his opinion that although Christopher Wren may not have designed it himself some pupil or master mason of his may have done so, and that the stairs also show signs of Wren's influence and were probably the work of one of his joiners.

The house was in the possession of the Earls of Harrington until 1917, when it was purchased by Cox's Bank. It was used by this firm of Army Bankers during the latter part of the war, and was acquired by the Postmaster-General in 1925.

The interesting staircase is illustrated in Fig. **4**, and is often referred to as Nell Gwynn's Staircase. This association is, however, hardly justified by the facts as that lady died in 1687, whilst the most reliable estimate of the date of the building of Harrington House is 1690.

[Figs. **1** and **3** are from photographs supplied by Messrs. Siemens Bros. & Co.]

TELEGRAPH AND TELEPHONE PLANT IN THE UNITED KINGDOM.

TELEPHONES AND WIRE MILEAGES. THE PROPERTY OF AND MAINTAINED BY THE POST OFFICE IN EACH ENGINEERING DISTRICT AS AT 30TH SEPT., 1931.

No. of Telephones owned and maintained by the Post Office.	Overhead Wire Mileages.				Engineering District.	Underground Wire Mileages.			
	Telegraph.	Trunk.	Exchange.	Spare.		Telegraph.	Trunk.	Exchange.	Spare.
723,865	593	3,940	53,199	84	London	25,521	116,089	2,931,185	56,761
98,059	2,225	21,156	72,819	3,208	S. Eastern.	4,000	75,116	334,511	33,861
102,571	4,439	35,299	72,525	3,676	S. Western.	23,620	23,044	234,751	65,979
82,895	6,282	40,920	77,219	6,948	Eastern.	24,784	56,307	184,125	78,950
114,431	8,505	46,166	70,386	4,741	N. Mid.	36,022	82,460	299,593	114,516
102,323	4,783	32,057	85,290	4,574	S. Mid.	15,205	45,501	269,095	93,115
65,200	4,408	30,942	63,872	3,598	S. Wales.	8,011	36,487	156,939	62,514
125,976	7,903	27,582	61,384	4,466	N. Wales.	14,209	44,600	360,518	129,322
176,888	1,331	14,914	46,304	3,723	S. Lancs.	15,544	92,307	574,830	81,533
106,597	6,108	30,845	54,025	3,921	N. Eastern	17,522	62,650	300,021	63,427
72,394	3,772	23,585	43,222	3,207	N. Western.	9,138	40,236	195,003	39,536
55,427	2,402	16,466	29,337	3,227	Northern.	9,951	26,290	165,990	42,103
25,833	4,292	9,824	15,817	748	Ireland N.	141	3,131	60,331	2,686
77,353	4,542	28,923	45,964	1,532	Scotland E.	8,067	22,014	172,352	54,347
99,801	7,247	26,054	48,574	1,245	Scotland W.	12,005	32,333	254,085	32,096
2,029,613	68,832	388,673	839,937	48,898	Total	223,740	758,565	6,493,239	950,743
2,014,539	69,182	387,775	830,367	48,378	Figures as at 30 June, 1931	221,104	731,137	6,346,196	880,182

ACORN EXCHANGE.

PROGRESSIVE INSTALLATION OF THE NEW STANDARD OPEN TYPE RACKS AND SHELVES.

B. Houghton Brown,
Engineering Division, Standard Telephones & Cables, Limited.

THE concluding paragraph of my last article stated that Acorn Exchange was practically completed, and that it was hoped in this issue of the Journal we should be able to report the successful cut-over, and conclude with a few photographs showing this ceremony in progress. The cut-over date, however, has now been settled for January 7th, and will not take place until after the January issue of this Journal has been to print. We will therefore have to content ourselves with a few photographs showing less conventional, though it is hoped none the less interesting views of the equipment.

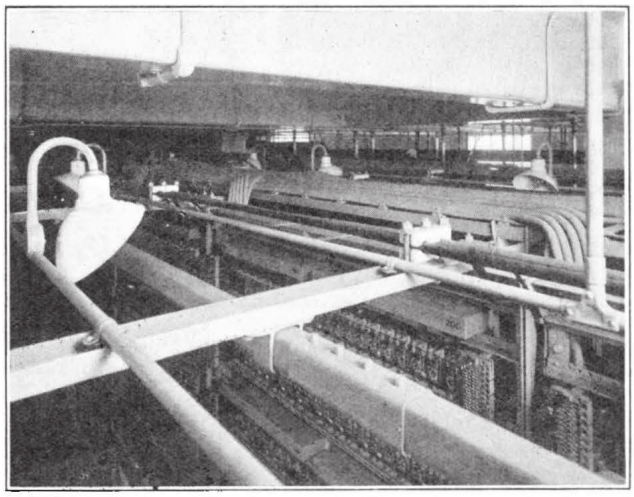


Fig. 21.

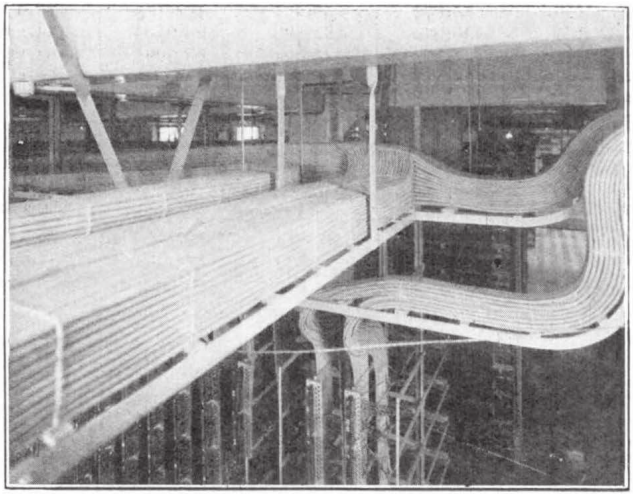


Fig. 22.

Fig. **21** was taken from the top of the cable runways, and is interesting in that it shows :—

(*a*) How the height of the racks has been considered in conjunction with the room height, giving the minimum ceiling clearance necessary for cabling and inspection purposes.

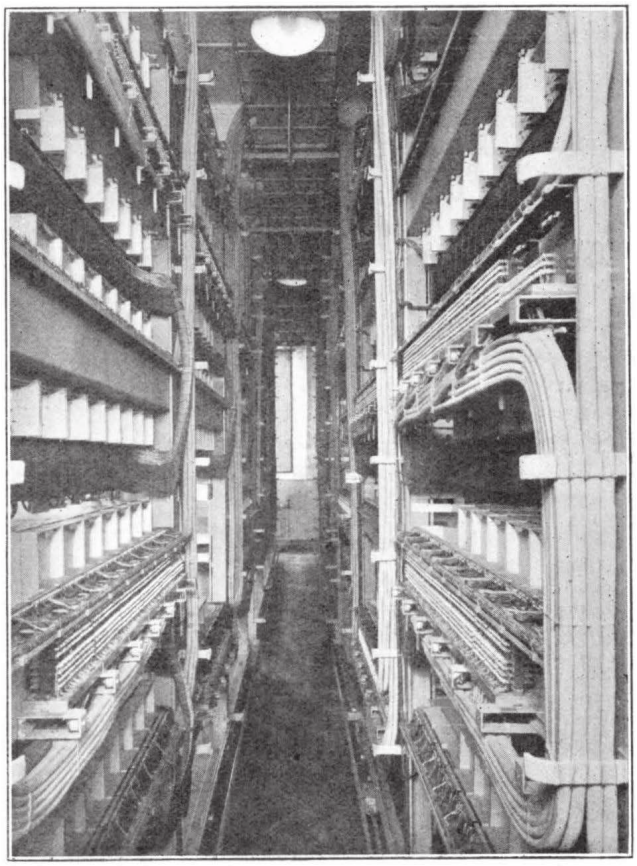


Fig. 23.

(*b*) The self-supporting qualities of the racks, the minimum number of ceiling supports being required.

(*c*) The use to which the intersuite stays are put. From left to right these are :—

(1) Supports the flood lighting conduit.

(2) Supports the travelling ladder overhead track.

FIG. **24**.

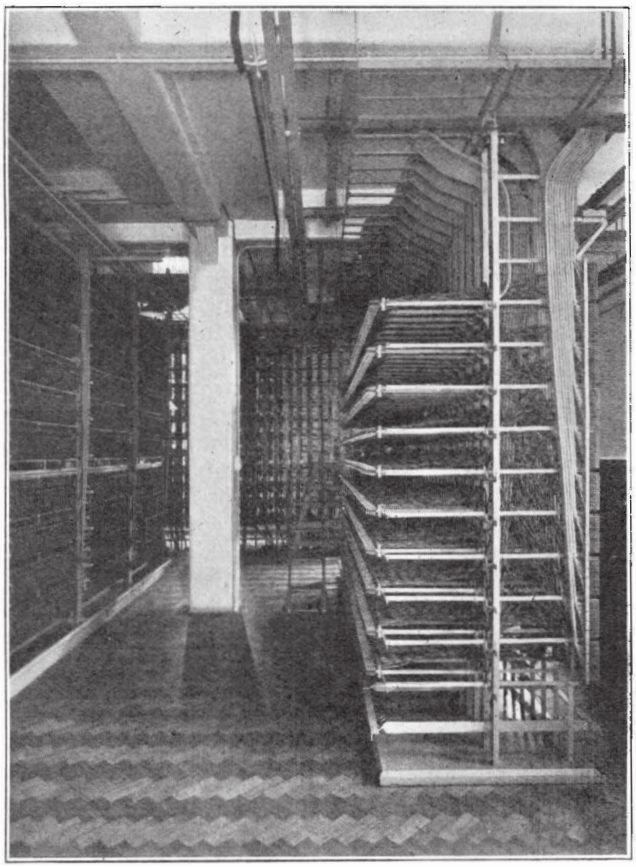


FIG. **25**.

(3) Supports the Suite busbars.
(4) Supports the Cable runways.

(*d*) The method of feeding cables from the cable runways to the rack terminal strips.
(*e*) The general scheme of flood lighting.
(*f*) The busbar distribution scheme.

Fig. **22** shows the main cable runways feeding the I.D.F. and gives a good idea of the care and patience which has to be exercised in handling large quantities of cables all feeding from different angles and levels. The standardisation of the height of the racks to 10′ 6″ has done a great deal to simplify the Installer's job from a cabling point of view, but this figure

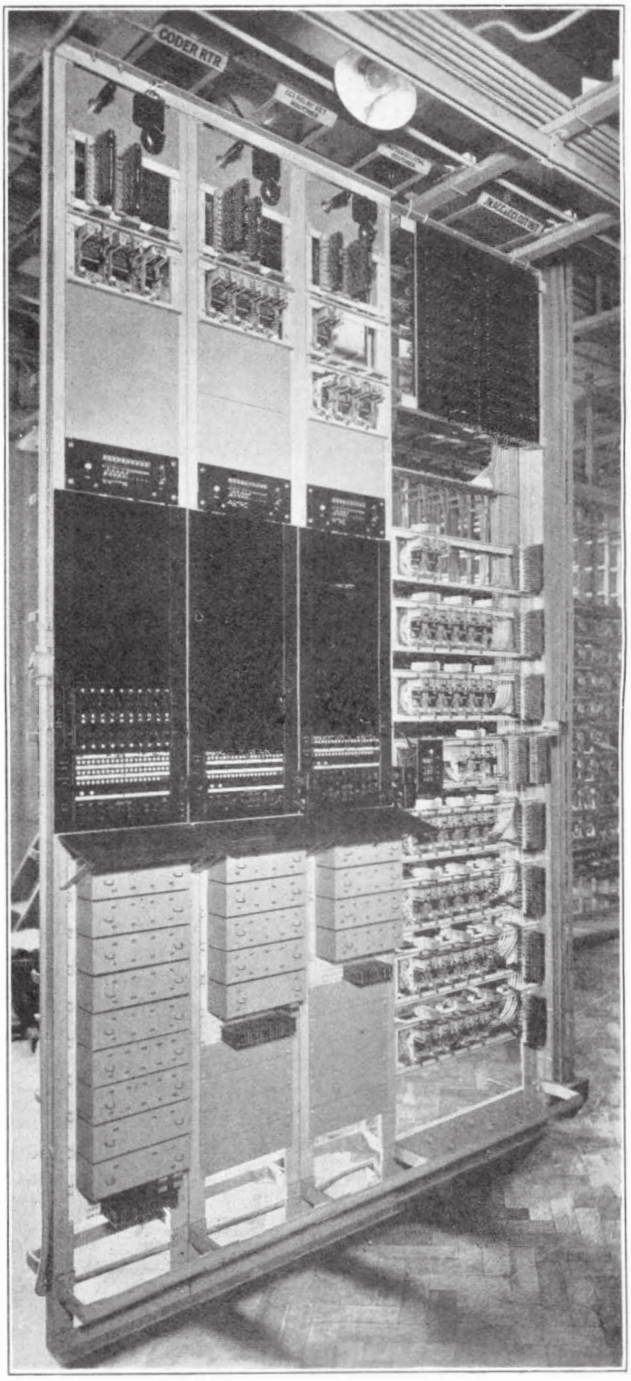


FIG. **26**.

impresses on one the enormous importance of arranging the floor plan not only to give the most economical rack lay-out but also to give the best cabling lay-out.

Fig. **23** shows the wiring gangway between two suites of group selectors, and the method of feeding the incoming and tie cables to the shelf terminal strips can be seen and should be compared with that shown in Fig. **24**, which represents the latest method to be adopted, consisting of butting the cables at the end of the shelf and forming out to the terminal strips. In addition to the change in the method of cabling, the shelves for subsequent Exchanges are now fitted with small dust covers protecting the wiring to the selector jacks.

Fig. **25** is included as a matter of general interest, inasmuch as it completes the series of photographs taken at different stages during the erection and cabling of the I.D.F., and shows the frame completely jumpered and ready for service.

Fig. **26** gives an idea of the development that has been made in the art of automatic routine testing and shows the Coder, C.C.I. Relay Set and C.C.I. Junction Routiner, together with the Auto and C.C.I. Access Equipment.

It will be noticed that these racks have not been built up on the open type channel shelf basis, as it is not considered that the circuits are sufficiently standard to warrant their inclusion on the new channel type base.

At the time of writing this article the " call through " tests had been carried out successfully, and the whole equipment was in the hands of the Department's representatives. In these same hands lies also the delicate task of developing the auto-mindedness of 10,000 subscribers, which, next to the correct functioning of the exchange equipment, contributes most to the success of the automatic system.

LINE FINDER DEVELOPMENTS IN THE BRITISH TELEPHONE SYSTEM, USING 2-MOTION SELECTORS.

W. A. Phillips, A.M.I.E.E., and R. Taylor,
Engineering Department, Automatic Telephone Manufacturing Company, Limited.

DURING the last ten years, the technique and application of automatic telephone switching methods have been very greatly extended. Whilst these developments include several important applications, this article deals solely with the recently developed line finder system. It may be said that this system represents an important step in automatic telephone development and is the result of intensive study, research and co-operation between the Department's engineers and those of the manufacturers.

This new line finder system is known as the partial secondary line finder, and differs from previously known finder systems in that fewer first selectors are required than finders. In the rotary switch system each subscriber was provided with an individual uniselector for selecting an idle conversational selector, there being in this system a minimum number of conversational selectors. In the earlier finder system the individual subscriber's uniselector was eliminated and the number of conversational selectors increased, but the nett result gave a saving over the rotary line switch system. With the new partial secondary finder, however, the advantages of both the rotary line switch system and the earlier finder system are retained, with the result that a minimum amount of line equipment is used, combined with a minimum number of conversational selectors. It will be obvious from the following description that this new line finder is equally applicable to both provincial and metropolitan areas.

Briefly, the adoption of the line finder system means that the amount of line equipment provided for each subscriber's line will be very considerably reduced, since the provision of a uniselector per line will be eliminated. Instead, each 200 lines group of subscribers will be served by a common group of from 12 to 30 line finders, of the standard two-motion type, depending upon the amount of traffic originated by each group. Full preselection of the line finders is ensured and two, three or more line finders are arranged to hunt simultaneously in each group, as may be required for the purpose of extending calling lines to the first selectors with a minimum of delay.

Fig. **1** shows the fundamental principle of the line finder system. Certain contacts of the line relays of each 200 lines group are commoned and control the divided starting arrangements. When a call is originated in any group, the operation of the line relay operates one of the start relays, at the same time " marking " the particular private bank contacts of the calling line on the finder multiple. The operation of the start relay immediately causes a preselected finder to hunt vertically and then horizontally until the calling line is found, whereupon the finder extends the calling line through to the 1st selector, and dial tone is then transmitted to the calling party. Simultaneously with the switching through to the selector, the calling subscriber's cut-off relay is actuated, thereby disconnecting the

common start circuit. The releasing of the start relay causes the allotter to preselect the next finder in the group in readiness to deal with the next originating call.

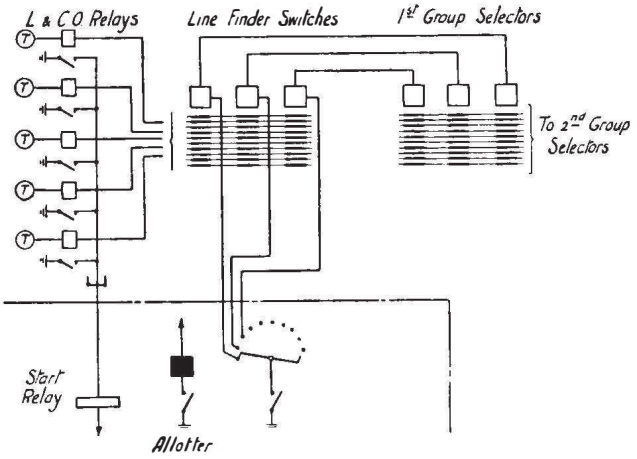


FIG. 1.

The finders are of the 200-point type, as shown in Fig. **2**. These finders are of identically the same general construction as group and final selectors, except that they are arranged to hunt both vertically and horizontally. To secure the vertical hunting action a set of vertical interrupter contacts is fitted and arranged to be actuated by the vertical armature. In addition, a small 11-point vertical bank and wiper is fitted to control the vertical hunting action. When seized by a calling subscriber, the line finder hunts vertically to the particular level on which the calling line terminates, the wipers then automatically cut-in on that level and are rotated to the calling line, which is immediately extended to a 1st selector.

The preselection of the line finders is automatically secured by means of allotters and relay sets, two, three or more of which are provided for each group of 200 subscribers' lines. The allotters are of the eight-level, heavy-duty, uniselector type.

In regard therefore to the quantity of subscribers' line equipment, the line finder system secures very considerable economies in comparison with the uniselector system, since, for a group of 200 subscribers, an average of, say, 20 line finders and three uniselectors are required instead of 200 uniselectors. Furthermore, this difference in line equipment is bound to react with beneficial results in regard to maintenance, since generally only one type of mechanism, *i.e.*, the standard two-motion selector, is used.

As is well known, step-by-step line finder equipments are already extensively employed on public exchanges in America, aggregating over three-quarter of a million lines in several hundred exchanges. Attention, however, is drawn to the fact that the Department's new system is fundamentally improved in that the finders per 200 lines are in a common group, the bank multiple is without slip or transposition, chain contact couplings have been eliminated, and allotters determine the order in which the finders shall operate (preventing disruption of service by a faulty finder). Further, the arrangement is self-routining.

An important feature also included in the new system is that of partial secondary trunking, which

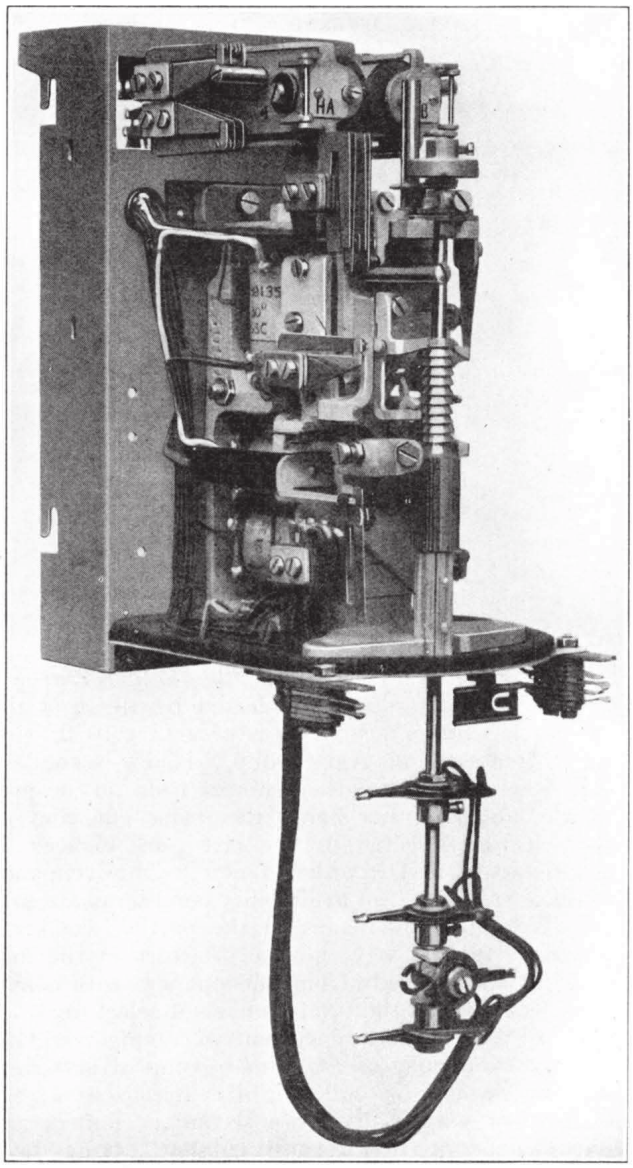


FIG. 2.

secures increased traffic carrying efficiency of the first selectors, with a minimum amount of secondary apparatus. This may be explained as follows :—

The minimum number of 1st selectors occurs when full availability conditions exist and this can only be provided by a system employing full secondary working. Now, as is well known, the traffic carried by selectors selected by earlier choices in a group is very much greater than those selected

by later choices and, in a group of say twenty selectors, the actual traffic that may be carried by each selector in successive choices, with a grade of service of 1 in 500, is as given in the following table :—

GROUP OF 20 SELECTORS.

FULL AVAILABILITY.

TRAFFIC OFFERED = 10.07 T.U.

Choice.	*Traffic carried.*
1	0.910 T.U.
2	0.897 T.U.
3	0.876 T.U.
4	0.857 T.U.
5	0.828 T.U.
6	0.796 T.U.
7	0.756 T.U.
8	0.703 T.U.
9	0.652 T.U.
10	0.588 T.U.
11	0.516 T.U.
12	0.441 T.U.
13	0.359 T.U.
14	0.283 T.U.
15	0.210 T.U.
16	0.148 T.U.
17	0.098 T.U.
18	0.063 T.U.
19	0.036 T.U.
20	0.020 T.U.

It may be said that, as the traffic carrying efficiency of the selectors selected by the first ten choices is satisfactory, it is unnecessary to provide access to these from every group. Hence, secondary apparatus for these earlier choices need not be provided. On the other hand, the traffic efficiency of the selectors selected by the last ten choices is unsatisfactory and, in order to increase the occupancy of these switches, full availability conditions are provided for them by means of the partial secondary scheme. In this way, all the selectors in the first rank are maintained at high occupancy, with consequent economy in the total number of selectors.

If a full secondary system were employed, the average occupancy of the whole group of first rank selectors would be only slightly increased, at the expense of very many more secondary finders and their attendant wiring and cabling. It has been found that the most economical results are obtained when approximately half the primary finders are connected direct to 1st selectors and the traffic from the remainder is concentrated by means of secondary finders. The two classes of primary line finders are, for convenience, designated regular and auxiliary finders respectively.

Before considering in detail the circuit—Fig. **3**—and the facilities provided by the new line finder system, brief mention may be made here of the main principles and requirements upon which the circuit arrangements have been designed. These are :—

(1) Minimum delay in extending any calling loop to a selector.
This has been accomplished by divided starting arrangements, permitting two, three or more finders to hunt simultaneously as may be required when subscribers in the same group originate calls at the same time.
(2) Provide for either single fee or multi-fee metering.
(3) Eliminate booster battery from subscriber's private normal wires—this prevents the remote, yet otherwise possible, false operation of final selectors.
(4) Prevent booster battery from causing false operation of finders.
For this purpose, cuprous oxide rectifiers are employed in series with the PA and PB relays.
(5) Ensure maximum occupancy of 1st selectors.
This is accomplished by a system of partial secondary trunking.
(6) Entire elimination of any possibility of dual connections.

Investigations also readily demonstrated that finders of the 200-point type were more economical than those of 25-, 50- and 100-point types. It was also clear that the two-motion selector was particularly suitable, since it provides the speediest means of testing 200 sets of contacts with a minimum of contacts wiped per call.

In regard to the secondary finders, it was established that the general case would be best met by 50-point uniselectors, although on installations of small sizes, 25-point secondary uniselectors would be satisfactory.

Facilities provided.

(1) Connects a calling line to a selector.
(2) Connects normal traffic direct from the line finder to a selector.
(3) Connects peak traffic *via* the line finder and a secondary finder to its associated selector. The secondary arrangements approach full availability conditions and increase the average occupany of the selectors.
(4) Two or more line finders may hunt simultaneously through the instrumentality of divided starting arrangements and a plurality of primary control sets, which are automatically regulated in accordance with the traffic.
(5) Any number of control sets, and consequently any number of finders may be arranged to hunt simultaneously, by changing primary start relay set.
(6) Gives uniform loads to control sets.
(7) Gives an alarm if a control set fails.
(8) Busies faulty equipment and completes the call *via* a partner control set.
(9) Gives a plurality of controls at each stage.
(10) Provides full preselection of finders.

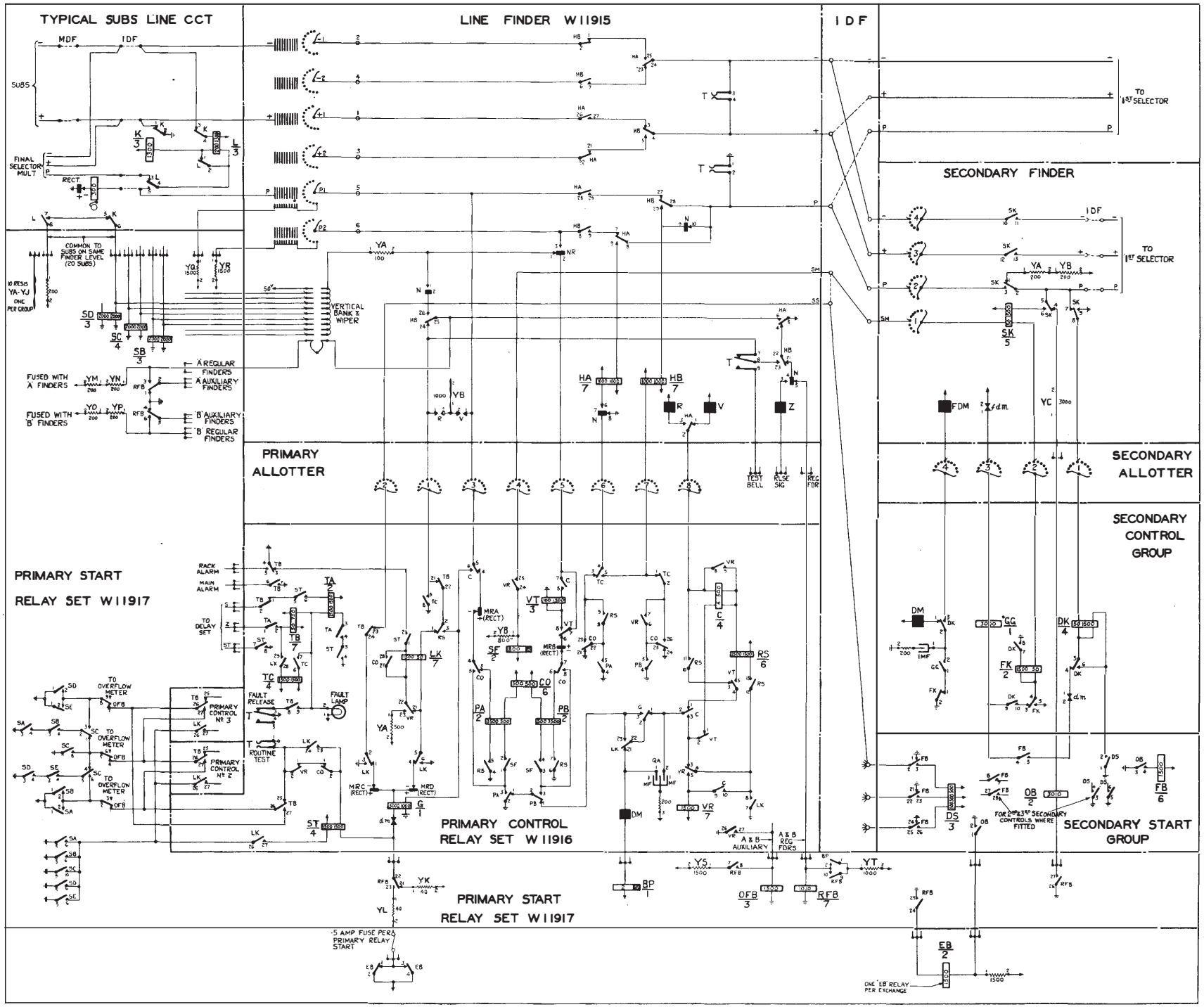


FIG. 3.—LINE FINDER CIRCUIT.

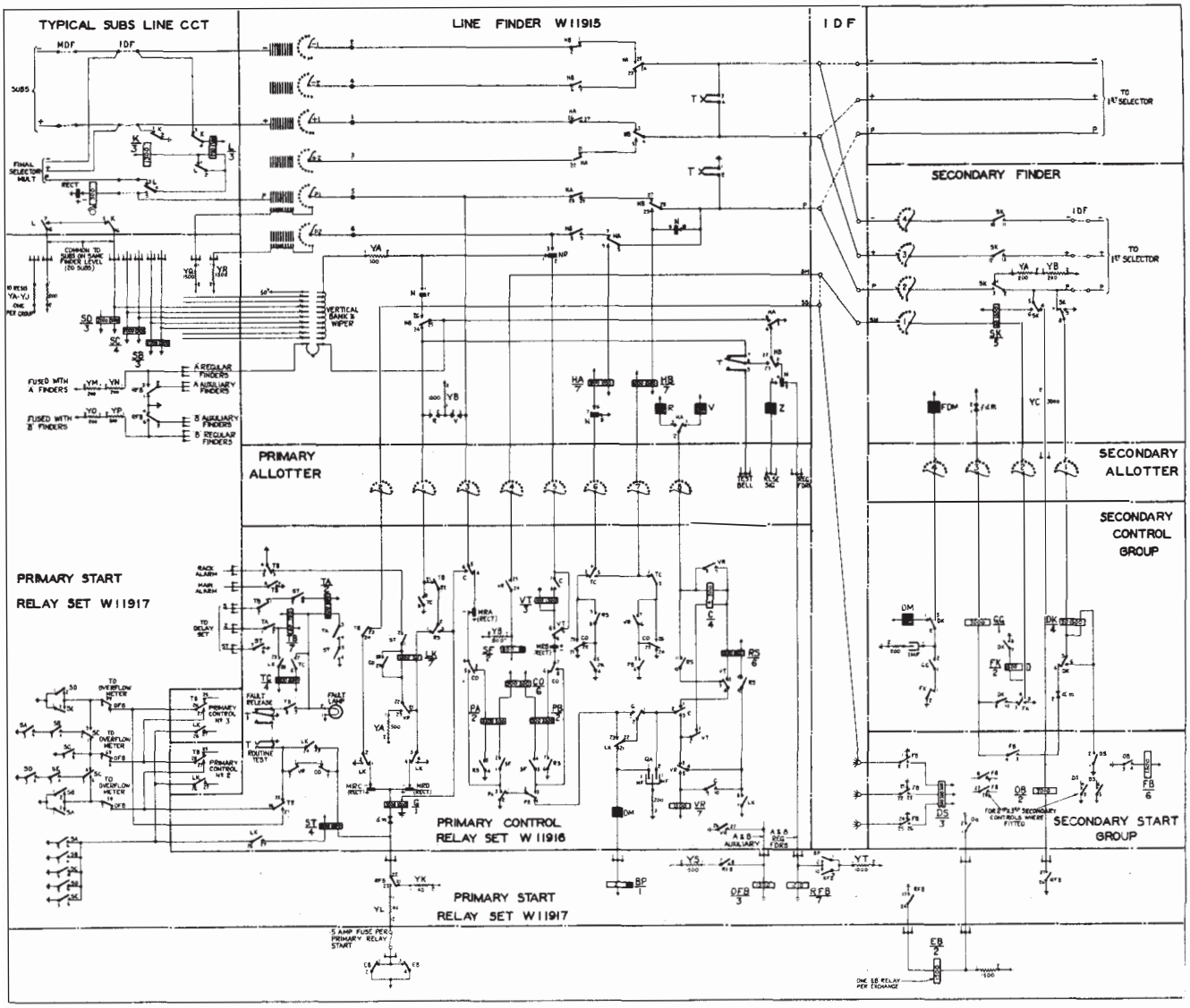


FIG. 3.

(11) Gives overflow metering when all finders in a group are simultaneously engaged.

(12) Prevents continuous rotation of allotters when all finders are simultaneously engaged.

(13) Reduces " stealing " to a minimum by preventing double searching on a particular level of line finders.

(14) Reduces to a minimum the time taken to find the calling line. Average time 0.5 seconds.

(15) Gives full line finder 1st selector I.D.F. facilities, enabling any line finder or secondary finder to be jumpered to any 1st selector for load distribution.

(16) Provides test bell facilities to distinguish readily between " odd " and " even " switching of line finders.

(17) Provides individual release of line finders.

(18) Gives release magnet alarm in the event of line finder failing to restore.

(19) Provides divided fusing of line finders to prevent traffic dislocation.

(20) A subscriber's faulty line or equipment has no influence on the service to other subscribers on the same finder level.

(21) Provides for busying line finder or secondary finder from associated selector or busying of line finder by inserting busy marker in the test jack of selector or line finder.

(22) Provides for automatic self routining of finders.

(23) Provides for manual routining of line finders by insertion of a busy marker in the test jack springs of the primary control set.

(24) Suitable for use with any standard 3-wire

booster metering system.
(25) Provides for single or multi-fee metering.
(26) Gives immediate guard to the private normal wire of calling subscriber's line.
(27) Eliminates booster metering connection to the private normal wire, *i.e.*, prevents a remote, yet otherwise possible, false operation of final selectors.
(28) Eliminates false switching to a subscriber, *i.e.*, if testing an engaged line having booster battery on release trunk, the line finder will not switch through.
(29) Employs battery testing principles throughout.
(30) Does not employ sequence adjustment of relay springs, *i.e.*, " X " and " Y " contacts eliminated.
(31) Provides a standard grade of service with maximum economy.

Circuit Operation.

Subscriber's Line Circuit.—When a subscriber's line is looped to initiate a call, the line relay operates *via* its 1300-ohm winding. At disconnected contacts L3 and 4, the private normal wire is immediately guarded against intrusion, whilst the corresponding private contacts of the finder multiple are " marked " with battery *via* winding of relay K, 200-ohm winding of relay L and operated contacts L4 and 5. Simultaneously the particular level of the vertical bank is marked with battery *via* the 200-ohm resistance, operated contacts L6 and 7 and normal contacts K5 and 6, and the corresponding relay SA, SB, SC, SD or SE is also operated over the same circuit. With the operation of any of these latter five relays, the start relay ST, in the primary control relay set, operates and causes a preselected finder to hunt and extend the calling line to its associated 1st selector. The detailed operation of the finder is explained later.

Immediately the finder extends the line through to the selector, earth is fed back over the private wire to operate the calling subscriber's K relay *via* the private bank of the finder, operated contacts L4 and 5, 200-ohm winding of relay L, etc., relay L also being held operated. At this time dialling tone is transmitted to the calling subscriber, who may then complete the call.

Metering.—As previously mentioned, both single fee and multiple fee metering are provided for on the booster principle. The subscriber's meter is connected from the finder bank private wire direct to earth through a small metal rectifier. For multi-fee metering, the meter is operated one or more times according to the number of separate metering impulses, which are automatically transmitted according to the destination of each call. The method of operation of the meter will be clear from the attached schematic diagram, Fig. **4**.

The subscriber's line and cut-off relays being normal, current is prevented from passing from earth *via* the meter winding, due to the potential of the negative plate of the metal rectifier tending to

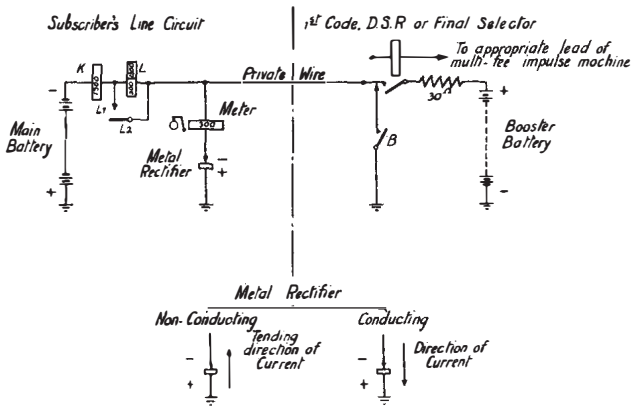


FIG. **4**.

be lower than its positive plate, under which condition the rectifier is non-conducting. When a subscriber's line is switched through to a final selector and the called subscriber replies, one or more booster metering impulses are transmitted for the metering operation, during which the private wire is intermittently raised from earth potential to approximately 50 volts positive. Hence, the negative plate of the rectifier being at higher potential than the positive plate, the subscriber's meter is operated and released a number of times corresponding to the impulses transmitted.

Incoming Calls.—On incoming calls the subscriber's K relay operates in series with the switching relay of the final selector, and this disconnects the line relay, clearing the line for conversation.

Line Finding.—As previously mentioned, each group of 200 subscribers' lines is served by a common group of from 12 to 30 line finders, arranged to be fully pre-selected by means of allotters. Each group of line finders is divided into two sub-groups, regular line finders and auxiliary line finders. Whilst a 1st selector is directly connected to the regular line finders, the auxiliary finders gain access to a 1st selector *via* secondary finders of the uniselector type. Generally the regular and auxiliary finders are provided in approximately equal numbers for each group. The reason for this sub-division of the finders is to ensure maximum occupancy of the 1st selectors and consequent economy in selector quantities. The auxiliary finders are only brought into service when all the regular finders are simultaneously engaged, the control being entirely automatic.

The line finding apparatus in each group of finder switches comprises the following :—

(1) Primary start relay set.
(2) Primary control relay sets and allotters.
(3) Primary line finders (two-motion selectors).
(4) Secondary start group.
(5) Secondary control group and allotters.
(6) Secondary line finders (uniselectors).

Primary Start Relay Set.—Referring to the diagram, it will be seen that various contacts of the line and cut-off relays of the twenty subscribers on each level are commoned together. The L6 and 7

contacts are commoned to battery through a 200-ohm resistance, whilst the K5 and 6 contacts are commoned to one winding of the five double wound start relays, SA, SB, SC, SD and SE. For convenience, relays SA and SE are not shown in the diagram. The K5 and 6 commons are also extended to the corresponding first nine level contacts of the vertical bank, the top level contact being connected direct to battery. Thus when a subscriber's line or a number of subscribers' lines on different levels are looped, one or more of the start relays are operated, and, in addition, the corresponding level or levels are " marked " with battery, through the 200-ohm common resistances.

The operation of one or more of the start relays causes one or more finders to hunt for the calling lines. The diagram provides for the simultaneous hunting of a maximum of three finders, this being an average quantity, although less or more may be provided as required. The hunting of the finders is controlled by primary control relay sets, three such sets being provided for in the diagram. If only one start relay is operated, only one finder hunts. If any two start relays are simultaneously operated, two finders hunt together, whilst if any three relays are operated, three finders hunt. In all there are 24 possible combinations of single, double and triple operations of the start relays and the particular arrangement of the contacts of these relays ensures that, no matter what combination occurs, the required number of finders is brought into operation.

It will be observed that each of the line start relays is controlled by two levels of subscribers' lines, *i.e.*, a total of forty lines. In the event of two or more subscribers in any forty initiating calls at one and the same time, these calls are rapidly put through by separate finders, which are seized in succession by the automatic stepping action of the allotter, as will appear later.

Primary Control Relay Set, Allotter and Primary Line Finder.—It is convenient to consider these together and to bear in mind that, when a call is being initiated, a preselected finder is immediately caused to hunt, first for the calling level which is marked with " battery " on the vertical bank and, secondly, for the particular subscriber's private bank contact which is marked with battery, *via* operated contacts L4 and 5, 200-ohm winding of relay L and winding of relay K to battery.

Assuming that start relay SA in the primary start set is operated, the circuit for relay ST in the primary control set is completed from earth at operated contacts SA 1 and 2, normal contacts OFB 2 and 1, TB 26 and 25, VR 2 and 1, CO 1 and 2, 1500-ohm winding of relay ST, normal contacts RFB 22 and 21, 40-ohm resistance to battery. Relay ST therefore operates and in turn operates relay LK from earth at normal contacts TB 4 and 3, operated contacts ST 2 and 1, 1500-ohm winding relay LK, normal contacts VR 22 and 21, 50-ohm winding relay LK, normal contacts RS 1 and 2, TB 22 and 21, wiper and bank 1, normal contacts HB 24 and 25, vertical wiper and contacts, the two 200-ohm resistances YN and YM to battery.

With the operation of relay LK the vertical magnet circuit is completed as follows :—Battery through vertical magnet V, normal contacts HA, bank and wiper 8 of allotter, 500-ohm and 4-ohm windings of relay C, normal contacts VT 1 and 2, VR 3 and 4 and operated contacts LK 8 and 7 to earth. At this stage the vertical magnet is not fully energised, due to the 500-ohm winding of relay C. The latter relay, however, operates and, at operated contacts C 9 and 10 and LK 8 and 7, operates VR, which locks up *via* operated contacts VR 5 and 4. The operation of relay VR now causes relay HB to operate from battery on one winding, bank and wiper 7 of allotter, normal contacts TC 1 and 2, operated contacts VR 7 and 6 and normal contacts CO 25 and 24 to earth. Relay HB short-circuits the 50-ohm winding of relay LK from earth at operated contacts LK 5 and 6, 50-ohm winding LK, normal contacts RS 1 and 2, TB 22 and 21, wiper 1 and contact of allotter, test jack T, operated contacts HB 23 and 22 and normal contacts HA 4 and 5 to earth. Relay LK is however held operated from battery on 500-ohm resistance YA, operated contacts VR 23 and 22, 1500-ohm winding LK, operated contacts ST 1 and 2 and normal contacts TB 3 and 4 to earth.

Vertical Stepping Action.—The operation of relay VR also short-circuits the 500-ohm winding of relay C and thus causes the vertical magnet to be fully energised in series with the 4-ohm winding of relay C, normal contacts VT 1 and 2, operated contacts C 3 and 2, normal contacts G 1 and 2, operated contacts LK 22 and 23, and normal contacts PB 1 and 2 and PA 1 and 2 to earth.

The wipers of the finder switch are therefore stepped to the first level and, assuming that the calling level is the second, another vertical step is required. Simultaneously with the stepping of the wipers to the first level, the vertical interrupter contacts V close, and a 1000-ohm resistance battery is then fed *via* bank 3 and wiper of allotter, operated contacts 5 and 6 of relay C (which remains steadily operated during the vertical stepping action on account of its 500-ohm winding being short-circuited by operated contacts VR 8 and 9) to the 1000-ohm winding of relay G, which then operates. The operation of relay G opens the vertical magnet circuit at disconnected contacts G 2 and 1, thus releasing the vertical armature and so opening the vertical interrupter contacts, hence also releasing relay G. With the release of relay G, the vertical magnet is again fully energised, causing the wiper to be stepped to the second level, which in this case is the calling level. A circuit for relay VT is then completed from the " marking " battery on the second level of vertical bank, vertical wiper, 100-ohm resistance YA, rotary off-normal contacts NR, bank and wiper 5 of allotter, operated contacts C 7 and 8 and both windings of relay VT in series to earth. By this time relay G will have again operated to disconnect the vertical magnet circuit, following

which relay G will also be released.

With the release of relay G, a circuit is now completed for relay RS from battery through the vertical magnet, normal contacts HA 1 and 2, bank and wiper 8 of allotter, operated contacts VR 8 and 9, winding of relay RS, operated contacts VT 5 and 4, normal contacts 1 and 2 of relay C (now restored), normal contacts G 1 and 2, operated contacts LK 22 and 23, normal contacts PB 1 and 2 and PA 1 and 2 to earth. Relay RS therefore operates and locks up on its other winding and operated contacts RS 13 and 12, LK 8 and 7 to earth. The operation of relay RS now causes relay HA to operate from battery on one winding, operated off-normal contacts N 6 and 7, bank and wiper 6 of allotter, normal contacts TC 4 and 3, operated contacts RS 9 and 8 and normal contacts CO 22 and 21 to earth. Relay VT is now caused to be released by a shunting action from earth at operated contacts HA 5 and 6, HB 25 and 26, operated off normal contacts N 2 and 1, whilst at operated contacts HA 3 and 2, the rotary magnet is introduced in place of the vertical magnet.

Rotary Stepping Action.—The rotary magnet is now fully energised from battery through the magnet winding, operated contacts HA 3 and 2, bank and wiper 8 of the allotter, operated contacts RS 11 and 10, normal contacts VT 3 and 4, C 1 and 2, G 1 and 2, operated contacts LK 22 and 23, and normal contacts PB 1 and 2, PA 1 and 2 to earth. The wipers therefore cut-in on to the first set of contacts, whereupon the rotary interrupter contacts, R, make and complete the following circuit to operate relay G :— Battery, 1000-ohm resistance YB, operated R contacts, bank and wiper 1 of allotter, normal contacts TB 21 and 22, operated contacts RS 2 and 3 and 1000-ohm winding of relay G to earth. Relay G operates to disconnect the rotary magnet circuit at operated contacts G 3 and 2, thus in turn releasing relay G. Assuming that the calling line terminates on the fifth set of contacts in the level and that the calling number is an odd one, then the fifth contact of P1 bank will be marked with battery. The interaction of the rotary magnet and relay G therefore continues until the wipers reach the marked contact, whereupon the hunting action is arrested due to the operation in turn of relays PA and CO as follows :—

Battery through winding of calling subscriber's relay K, 200-ohm winding relay L, operated contacts L 4 and 5, P1 bank and wiper of finder switch, bank and wiper 3 of allotter, normal contacts C 5 and 4, metal rectifier (conducting in this direction), normal contacts CO 4 and 3, 3500-ohm winding relay PA and operated contacts RS 5 and 4. Relay PA operates and locks up on its other winding in series with relay CO, *via* operated contacts SF 2 and 1 and PA 3 and 2. Note—Relay SF was caused to operate when relay VR operated, over the following circuit :—Battery, winding of relay SF, operated contacts VR 24 and 25, bank and wiper 4 of allotter, strapping SM and SS at I.D.F. (since the operation of a regular finder is being considered), bank and wiper 2 of allotter, normal contacts TB 23 and 24 and operated contacts LK 2 and 3 to earth. The operation of relay CO disconnects the circuit of relay HB at operated contacts CO 25 and 26. Relay HB therefore releases and the calling subscriber's loop is then extended to the selector from earth and one winding of relay A on the selector, positive line, normal contacts HB 4 and 3, operated contacts HA 27 and 26, positive wiper and bank of finder, calling subscriber's looped line, negative bank and wiper, normal contacts HB 2 and 1, operated contacts HA 25 and 24, negative line, the other winding of relay A of the selector to battery. The A relay of the selector therefore operates and in turn operates relay B, which returns earth over the private wire to hold relay HA *via* operated contacts HA 8 and 9.

With the operation of relay CO, relay LK is also caused to release due to its 1500-ohm winding being short-circuited by operated contacts CO 27 and 28. The release of relay LK also releases relays RS and VR at restored contacts LK 8 and 7, and disconnects the circuit of relay SF at restored contacts LK 1 and 2. Relay SF, being fitted with a copper slug, releases after a brief delay and thus opens the holding circuit of relay CO and PA at restored contact SF 2 and 1. The delay in restoring relay CO and PA is to ensure adequate overlap between the return of earth over the P-wire, to hold relay HA on one winding, before the circuit of the other winding is disconnected at restored contacts CO 21 and 22 and PA 5 and 4.

It will be observed that, as both relays HA and HB are operated during the rotation of the wipers the circuit to the A relay of the selector is maintained opened, thus precluding any interference with other lines when passing over engaged contacts. The function of the metal rectifiers MRA and MRB, which are in series with the relays PA and PB, is to prevent false operation of the finders when passing over the P1 and P2 wires coincident with the application of the booster battery metering impulses. Under this condition the P-wires could be temporarily at positive potential with respect to earth, and the particular connections of the rectifiers renders them non-conducting.

If the calling number had been an even instead of an odd number, as assumed above, relay HA would have been released instead of relay HB and relay PB would have been operated instead of relay PA.

Preselection of next finder; Regular finder available.—The release of relay LK also energises relay G from battery on 40-ohm resistance YK, normal contacts RFB 21 and 22, allotter interrupter contacts LC, 3000-ohm winding relay G, metal rectifier MRD, normal contacts LK 4 and 5, 50-ohm winding relay LK (inoperative under this condition), normal contacts RS 1 and 2, TB 22 and 21, wiper and bank 1 of allotter and, either, normal contacts HB 24 and 25, operated contacts HA 6 and 5 to earth, or normal test jack contacts T, operated HB 23 and 22, normal contacts HA 4 and 5 to earth. Relay G operates and completes the allotter magnet circuit from battery, winding of relay BP, magnet winding,

normal contacts LK 21 and 22, operated contacts G 2 and 3 and normal contacts PB 1 and 2, and PA 1 and 2 to earth. The armature of the allotter is therefore attracted and, simultaneously with the engagement of the pawl with the ratchet wheel, the interrupter contacts LC open and thus release relay G, whereupon the wipers of the allotter are stepped to the next set of contacts. This interaction between relay G and the driving magnet continues until the allotter wiper 1 does not encounter full earth, whereupon the allotter stops and thus preselects a free finder associated with that particular contact.

It will be observed that, since in this case it has been assumed that a regular finder is available, the allotter hunts over the sets of contacts on which the auxiliary finders are terminated, because of the earth fed back from the normal RFB contacts in the primary start relay set, vertical bank and wiper, normal contacts HB 25 and 24, bank and wiper 1 of allotter, normal contacts TB 22 and 21 and RS 2 and 1, 50-ohm winding of relay LK, normal contacts LK 5 and 4, rectifier MRD, 3000-ohm winding of relay G, interrupter springs of allotter, normal contacts RFB 22 and 21, 50 ohms resistance to battery.

All regular finders simultaneously engaged.—In this case, the sets of contacts of the allotter associated with regular finders will all be earthed; consequently the allotter will pass over these contacts. Relay RFB, however, will be operated, thus operating relays OB and FB in the secondary start set and so removing the commoned earth at disconnected contacts FB 1 and 2, 21 and 22 and 24 and 25 from the contacts of bank 2 in the primary allotter. The preselection of auxiliary finders is performed by means of a double test by relay G. Thus, if a particular auxiliary finder is engaged, the associated contact on bank 1 of the primary allotter will be earthed, thus operating relay G and causing the allotter to step on. On the other hand, assuming a particular auxiliary finder to be free but that all the corresponding groups of secondary finders are simultaneously engaged, then the busying earth will be put back from the secondary start group to the contacts of bank 2 on the primary allotter. Under this condition relay G again operates and causes the allotter to step on until both a free auxiliary finder and a free secondary finder are preselected. This precludes the possibility of an auxiliary finder being actuated unless a free secondary finder, and consequently a selector are available.

Secondary finder apparatus.—Before dealing with the operation of the secondary finder apparatus, it will be convenient to assume that, in the present case, a total of not more than 25 finders will suffice for each group of 200 subscribers' lines. In this case, only one allotter is provided for each primary control relay set and the regular and auxiliary finders are connected to alternate sets of contacts of the allotter. If the number of finders is less than 25, the spare allotter contacts on bank 1 are earthed, or they may be cross-connected to provide a double appearance on the allotter bank contacts of some, at any rate, of the finders. When traffic considerations require that more auxiliary than regular finders are required, the excess auxiliary finders are connected to the allotter contacts immediately following the alternate sequence of regular and auxiliary.

Normally, when the traffic is light, only the regular finders can be preselected, the auxiliary finders being busied from earth at normal contacts RFB 1 and 2 and 4 and 5 in the primary start set. When the traffic is heavy, causing all the regular finders to be simultaneously engaged, relay RFB in the primary start relay set is caused to be operated in the following manner: The last regular finder having switched through, relay BP operates in series with the allotter driving magnet when it commences to hunt to preselect another finder. If the regular finders are all engaged, earth is removed from the commoned off-normal contacts N 4 and 5, which are now disconnected. Consequently, with the operation of relay BP, relay RFB operates and locks up *via* operated contacts RFB 9 and 10.

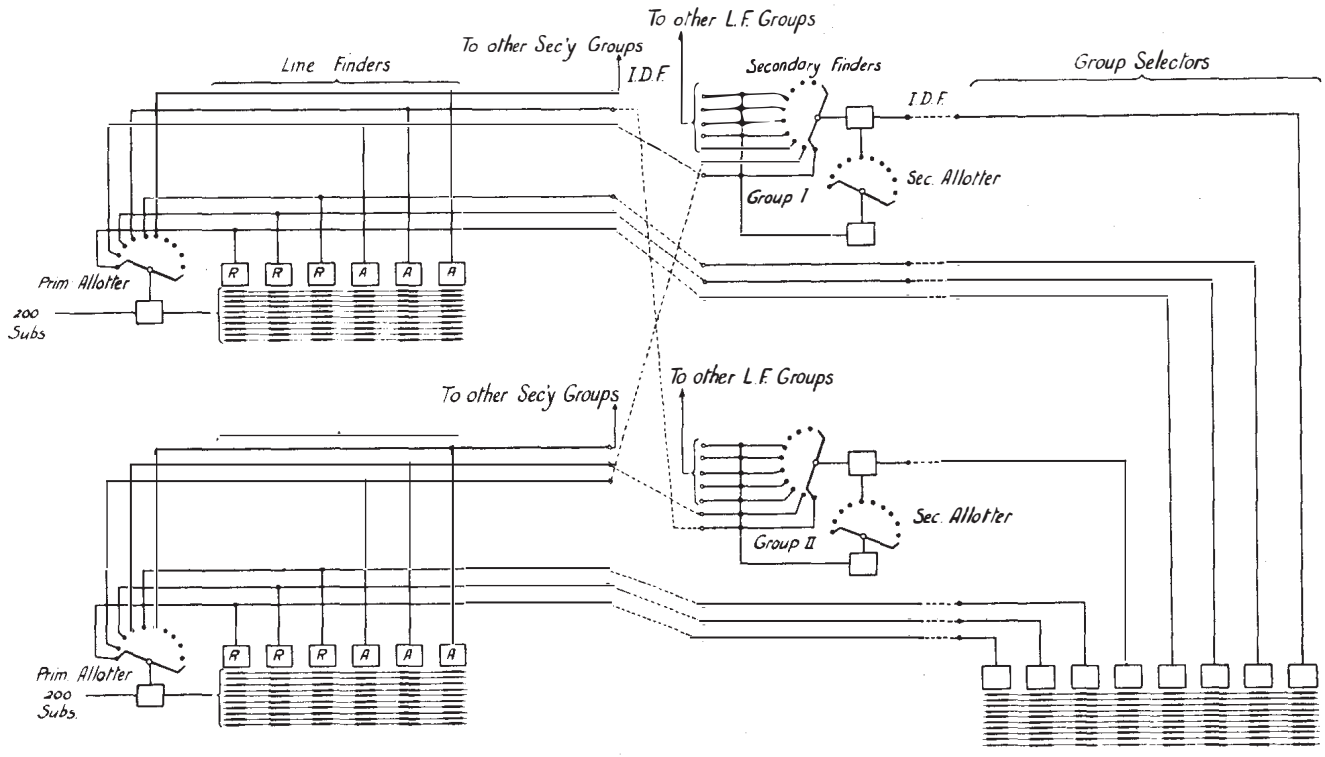
The operation of relay RFB now operates relay OB as follows:—Earth at operated contacts RFB 26 and 27, winding of relay OB, 3000-ohm resistance YC, normal contacts SK 4 and 5, SK 1 and 2, and the 200-ohm resistances YA and YB to battery. The operation of relay OB in turn operates relay FB, which thus removes, at disconnected contacts FB 1 and 2, 21 and 22, and 24 and 25, the commoned busying earth from the alternate even contacts of bank 2 of the primary allotters. Simultaneously, the battery feed to the auxiliary finders is established at operated contacts RFB 2 and 3, and 5 and 6, in the primary start set. When the primary control seizes an auxiliary finder, relay DS in the secondary start group is operated from battery on one of its windings, operated FB contacts, the particular even contact and wiper of bank 2 of the allotter, normal contacts TB 23 and 24, and operated contacts LK 2 and 3 to earth. The operation of relay DS now causes one, two or three (depending upon the particular arrangement in accordance with traffic requirements) secondary finders to hunt simultaneously to find the particular primary auxiliary finder being used, as follows:—At operated contacts DS 1 and 2, earth is extended through both windings of relay DK in series, wiper and bank 1 of secondary allotter, normal contacts SK 8 and 7, 2 and 1, the 200-ohms resistances YA and YB to battery. Relay DK operates and in turn operates relay GG of secondary control group from battery, interrupter contacts of secondary finder, bank and wiper 3 of secondary allotter, winding of relay GG, operated contacts DK 9 and 10, normal contacts FK 3 and 4, 1500-ohm winding of relay FK and operated contacts DK 7 and 8 to earth. Under this condition, relay FK does not operate on account of the high resistance of relay GG. The operation of relay GG now fully energises the driving magnet of the secondary finder *via* bank and wiper 4 of secondary allotter, operated contacts DK 3 and 2, GG 2 and 1, and normal contacts FK 1 and 2 to earth. When the armature of the secondary finder

is attracted, the interrupter contacts are opened to release relay GG, thus disconnecting the driving magnet and causing the wipers to take one step. This interaction between relay GG and the driving magnet continues until the wipers reach the contacts associated with the particular primary auxiliary finder, whereupon relay SK of the secondary finder operates over the following circuit :—Earth at operated contacts DK 8 and 7, both windings of relay FK in series, wiper and bank 2 of secondary allotter, 50-ohm winding of relay SK, wiper and bank 1 of secondary finder, bank and wiper 4 of primary allotter, operated contacts VR 25 and 24, winding of relay SF to battery. When relay FK short-circuits its 1500ω winding relays SK and SF operate and are held operated at operated contacts FK 4 and 5 to earth, until the primary control relay set is released. Whilst relay SK is then held by the earth returned over the P-wire from the selector, relay SF in the primary control set and relay FK in the secondary control set are both released, thus causing the primary allotter to preselect another primary finder and, in general also, causing the secondary finder to preselect another secondary finder in readiness for the next call. The preselecting feature of the primary allotter has already been dealt with, the corresponding action of the secondary allotter being as follows :—

So long as relay RFB remains operated, relays OB and FB will also be operated, provided any secondary finders are disengaged. Therefore, immediately a call is switched through a secondary finder to its selector, relay GG operates from battery, interrupter contacts of the secondary finder, winding of relay GG, operated contacts FB 4 and 5, interrupter contacts of secondary allotter, normal contacts DK 4 and 5, 50-ohm winding of relay DK (inoperative on account of high resistance of relay GG) wiper and bank 1 of secondary allotter and operated contacts SK 8 and 9 to earth. The driving magnet of the secondary allotter is therefore fully energised *via* normal contacts DK 1 and 2, operated contacts GG 2 and 1 and normal contacts FK 1 and 2 to earth. The interaction of the driving magnet and relay GG therefore continues until wiper 1 of the allotter encounters battery *via* the normal contacts SK 8 and 7, SK 2 and 1 and the 200-ohm resistances YA and YB of a free secondary, instead of earth on operated contacts SK 8 and 9 on engaged secondaries, whereupon relay GG fails to operate and thus causes the hunting action to cease.

It is important to observe that each secondary start group provides three access points from the primary allotters and is arranged to control two or three secondary allotters as determined by traffic considerations.

The plurality of secondary allotters causes a corresponding number of secondary finders to hunt simultaneously for the auxiliary line finder or finders marked by the primary allotter or allotters. The



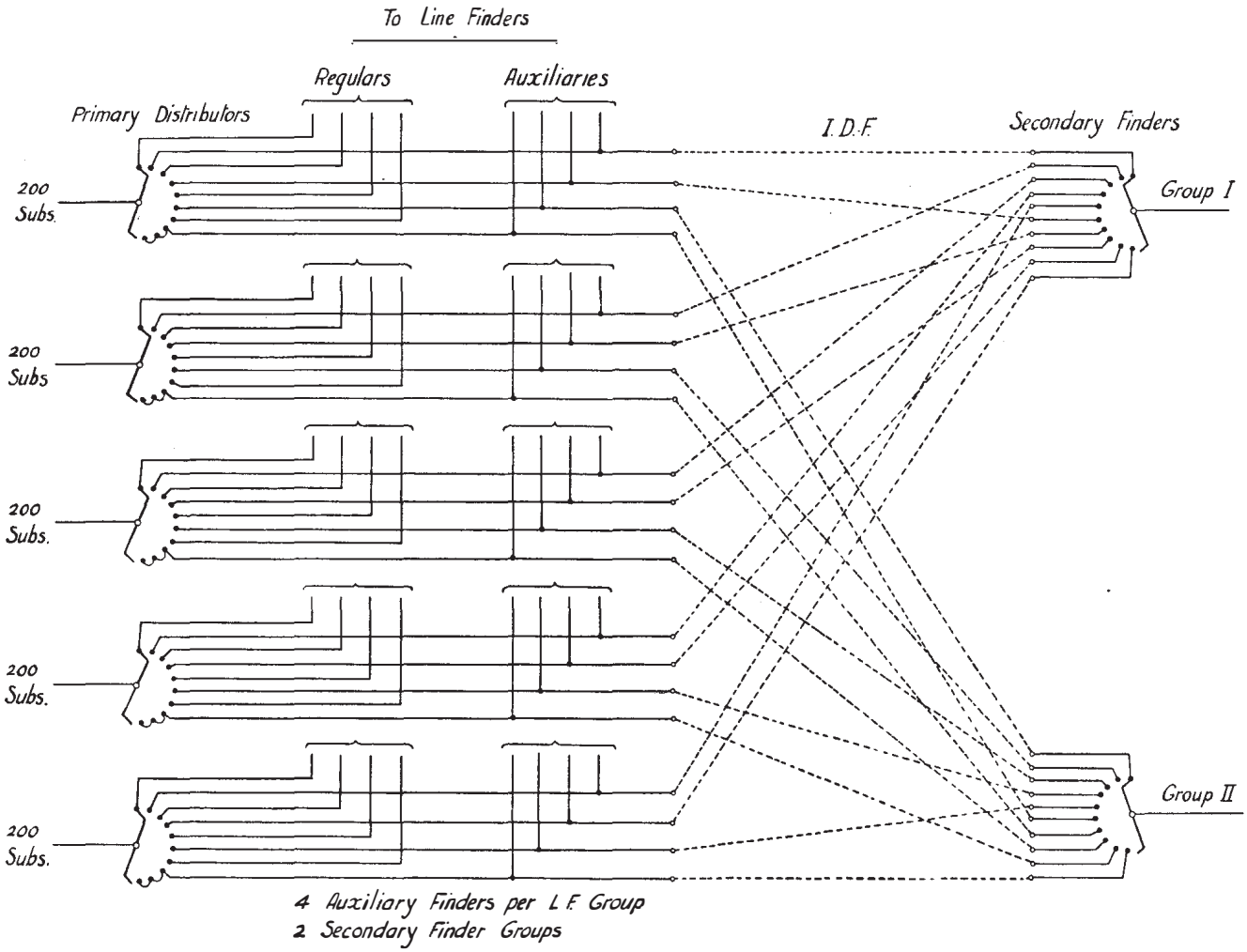
Trunking Arrangements of Partial Secondary Scheme

FIG. 5.

simultaneous hunting of two or three secondary finders reduces the delay in finding to a minimum. The multi-access points enable more than one primary allotter to switch to the same secondary group, thereby taking maximum advantage of the simultaneous hunting action. Any spare contacts of the secondary allotters may be commoned on bank 3 to the last secondary finder in the group, or, alternatively, they may be cross-connected to separate finders, which would then appear on two contacts of the bank.

When the total number of line finders in a group of 200 subscribers' lines exceeds 25, two primary allotters are fitted per control relay set. In this case the regular finders are connected to the first allotter and the auxiliary finders to the second allotter, an additional relay then being provided in the allotter to introduce the auxiliary finders when all the regular finders are simultaneously engaged. However, it will be only in cases of exceptionally heavy traffic that more than a total of 25 finders will be required per group of 200 subscribers' lines.

Maximum Accessibility to 1st Selectors ensured by Partial Secondary Trunking Scheme.—The employment of the partial secondary principle ensures that the regular line finders, selected by the earlier choices and which naturally carry the bulk of the traffic, have direct access to 1st selectors. The auxiliary line finders, selected by the later choices and which carry lower values of traffic, share access to 1st selectors with the auxiliary line finders of other groups. In this manner, maximum occupancy of the 1st selectors is obtained. Fig. **5** shows the general arrangement of the partial secondary trunking scheme, whilst Fig. **6** shows typical cross-connections between the auxiliary line finders and the secondary finder banks. It must be borne in mind that Fig. **6** is typical only, and that on an average exchange of about 3000 lines, there would be approximately 7 auxiliary finders in each of 15 groups and 4 groups of secondary finders. Fig. **6** however serves to show the principle, from which it will be observed that, assuming the extreme case in which not only are all the regular finders



Typical Cross Connections between Line Finders & Secondary Finder Banks - Partial Secondary Trunking Scheme

FIG. 6.

engaged in each group, but also that there is only one 1st selector free on the whole exchange, an auxiliary finder in each LF group will be preselected and the last available secondary finder will be held in readiness to hunt for the particular calling line finder, when the next call is made. Assuming now that this last call is put through and that the whole of the 1st selectors remain engaged, continuous rotation of the allotters is prevented in the following manner.

Prevention of Continuous Rotation of Allotters.

One EB relay is provided per exchange and is normally prevented from operating, when the regular finders in any group are all engaged, by the simultaneous operation of relay RFB in the primary start set and relay OB in the secondary start group. When, however, all the secondary line finders, and therefore all the 1st selectors are simultaneously engaged, all the OB relays in the secondary start groups will be normal, the circuits being opened at disconnected contacts SK 4 and 5. Under this condition relay EB operates and thus disconnects the common battery feed to all the primary allotters on the exchange, *via* operated contacts EB 1 and 2 and EB 3 and 4 in parallel.

The secondary allotters are also prevented from continuous rotation, since the OB and FB relays are all normal, thus disconnecting the circuit for the interrupter relay GG at the normal contacts FB 4 and 5.

Overflow Metering.

An overflow meter may be associated with each primary control relay set, one or other of these being actuated in the event of any call not being able to be put through. These meters are primarily controlled from relay OFB in the primary start relay set. Whilst battery is fed to relay OFB at operated contacts RFB 7 and 8 (when all the regular finders are simultaneously engaged), relay OFB does not operate until the last auxiliary finder in the group is not only off-normal but has actually switched through and the contacts VR 26 and 27 are opened. The whole of the finders in the group remaining engaged, the next call that is originated in the group causes one or other of the three overflow meters to be actuated.

Primary Control Set Alarm Signal.

If for any reason an originating call is not immediately switched through to a 1st selector, due to any abnormal condition arising in the line finding apparatus, both individual rack and main alarm signals are given in the following manner. With the operation of the start relay ST, which normally causes a preselected line finder to hunt for the calling line, the circuit for the delayed alarm set is completed at operated ST 7 and 8 and the " S " pulse then operates relay TA *via* normal contacts TB 2 and 1 and operated contacts ST 5 and 6. Relay TA locks up from battery on the 750-ohm winding of relay TB, 1500-ohm winding of relay TA and operated contacts TA 3 and 4 and ST 3 and 4 to earth, but relay TB remains normal under this condition. The operation of relay TA also prepares a circuit to the " Z " pulse lead *via* operated contacts TA 1 and 2 for the 50-ohm winding of relay TB and also for relay TC, *via* operated contacts 28 and 29 of relay LK (already operated). The " Z " pulse occurs three seconds after the " S " pulse and, if in the meantime the line finder has not switched through to the 1st selector, the " Z " pulse causes the operation of relays " TB " and " TC," both of which lock up *via* operated contacts TB 9 and 8 and normal contacts af fault release jack T. The alarm lamp also lights, whilst the rack and main alarm signals are given *via* operated contacts TB 5 and 4 and 6 and 7 respectively. This particular primary control set remains locked out pending inspection, whilst at operated contacts TB 26 and 27, the next primary control set is switched in for the purpose of routing the call *via* another allotter and finder. With the locking-out of the defective control set, the associated distributor is prevented from stepping on, due to the circuits for both windings of the interrupter relay GG being disconnected at operated contacts TB 23 and 24 and TB 21 and 22. This ensures that the particular line finder employed, which might have been the cause of the call not going through, is also locked-out, being busied *via* bank and wiper 1 of the allotter and operated contacts TC 8 and 9 to earth. Subsequently, after the cause of the trouble has been detected and remedied, the apparatus may be reintroduced into service by momentarily opening the fault release jack T.

Automatic Self-Routining of Finder Switches.

By inserting a busy marker in the routine test jack of the primary control set, the line finders not in use may be routined in rapid succession, the finders being automatically stepped to the tenth level and rotated to the eleventh contact, then automatically releasing. Both the regular and auxiliary finders may be routined but, to routine the auxiliaries, each regular finder must first be busied out by inserting individual busy markers into the regular finder test jacks. As the wipers of each finder reach the 11th contacts, either or both the PA and PB relays are operated to operate relay CO, thereby releasing relays LK, VR, RS, SF, etc., and, since neither relay HA nor relay HB are held operated, the release magnet Z is energised to release the finder.

Referring to the diagram it will be observed that, when the auxiliary finders are being routined, the regulars are " busied " on bank 1 of the allotter *via* normal contacts 7 and 6 of test jack T, operated contacts HB 22 and 23 and earth at normal contacts HA 4 and 5, since relay HB is held operated *via* normal contacts N 9 and 10 and the busy marker in the test jack.

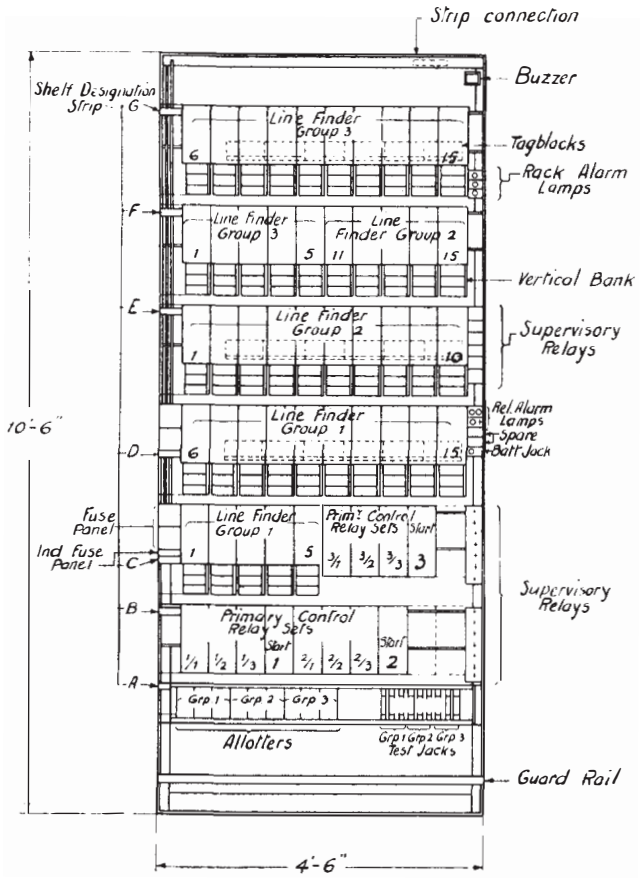
The circuit for operating relays PA and PB, upon reaching the 11th contacts, is established *via* the 1500-ohm resistances YQ and YR. The provision

of the second resistance ensures immunity from any possible tendency towards delayed cut-off of the rotary action upon reaching the 11th step, which might possibly arise if two finders arrive at the same time.

The routining may, of course, be carried out at any time without interfering with the service, since any finder that is being routined will pick up and switch through to a 1st selector if it encounters a " marked " contact. The allotter would then step on and the routining of the remaining finders would proceed.

Mounting Arrangements.

The new line finder equipment is arranged to be mounted on the standardised single-sided racks, the subscriber's L and CO relays and the line finders being mounted on separate racks. The L and CO relays are strip-mounted and are cabled direct to the I.D.F. The primary line finders, together with their complement of controlling relays and allotters, are mounted on the same rack, a typical arrangement being shown in Fig. **7**. As will be seen, this rack comprises three groups of finders. Fifteen finders, one primary start relay set, three primary control relay sets and three allotters are shown provided for each group. The battery feeding bus-bars and fuse panels are accommodated on the left hand side, whilst the supervisory relays and alarm lamps are fitted on the right hand side.



Line Finder Rack

FIG. **7**.

The secondary finders, together with their controlling relay sets and allotters, are mounted together in the form of self-contained shelves. Whilst on the smaller exchanges these shelves of secondary apparatus may be accommodated in any available space on the primary finder racks, on the larger exchanges they are mounted on separate racks.

Economies effected.

The graphs given in Figs. **8** and **9** show the economies effected by the new line finder system in comparison with the homing rotary line-switch system. Fig. **8** includes the cost of the subscriber's line equipment and first rank of selectors only, whilst Fig. **9** includes the whole of the automatic apparatus, *i.e.*, subscriber's line apparatus and all ranks of selectors, including the final selectors. The graphs indicate the effect of traffic intensity upon the relative cost, and since a traffic value of 0.035 T.U. per subscriber's line may be regarded as an average value, the average economy is substantial. It is only on very few occasions that an average traffic value of over 0.1 T.U. per subscriber's line is encountered in practice.

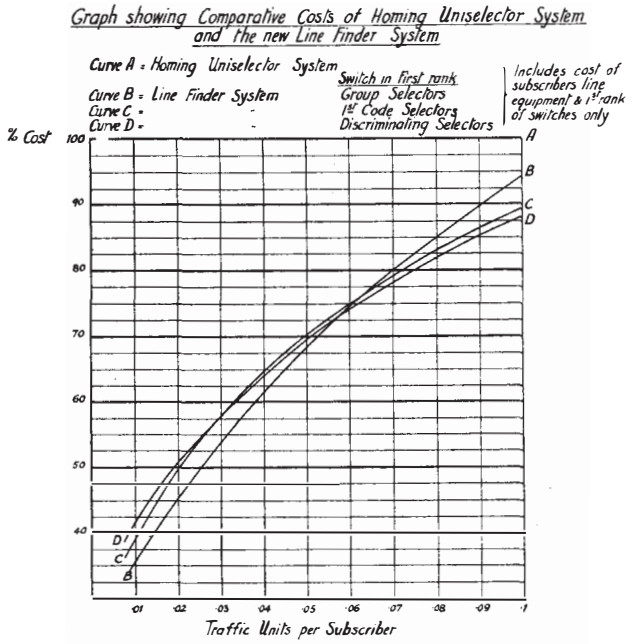


FIG. **8**.

The effect on economy of the cost of the 1st selectors is also brought out by the curves B, C and D. The cost of various types of 1st selector are in the following order, beginning with the least costly : —10/10 group selector, 10/20 group selector, 1st code selector, discriminating selector repeater.

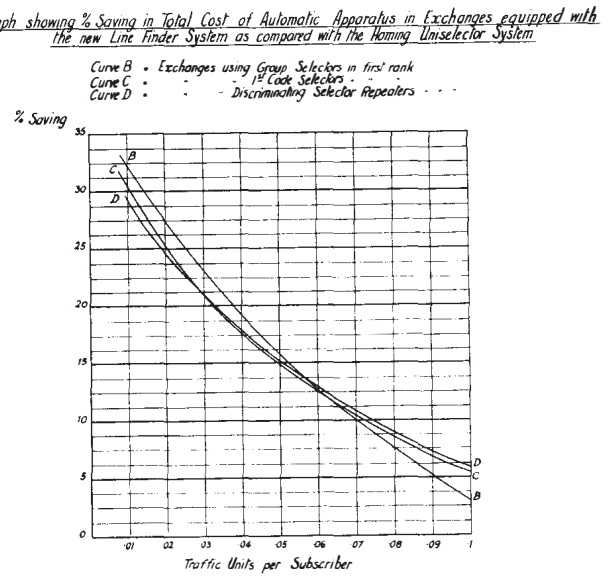


FIG. 9.

As may be supposed, the economy in first cost of the automatic apparatus also tends to economy in mounting space and hence reduces the size of exchange building that is required. Actually, a saving of approximately 30% in floor space will be effected in an average exchange equipped with line finder apparatus, as compared with the uniselector system. This figure is on the basis of both types of apparatus mounted on the standardised single-sided racks.

As previously mentioned, a saving in maintenance costs will also result, since practically all the switching apparatus will be one type, namely, the standard two-motion selector, instead of two, as in the case of the uniselector system. This will be obvious from Table I., which gives the quantities of uniselectors and two-motion selectors required for an average exchange equipped with the different systems :—

TABLE I.

3,000 LINES EXCHANGE. CALLING RATE 0.035 T.U. PER SUBSCRIBER.

	Uniselector system.	New Line Finder System.
Preselector—single-motion.	3,000	Nil
Line Finders—two-motion.	Nil	255
Primary Allotters—single-motion.	Nil	45
Secondary Line Finders—single-motion.	Nil	42
Secondary Allotters — single-motion.	Nil	9
1st. Group selectors.	163	162
Summary.		
Single-motion selectors.	3,000	96
Two-motion selectors.	163	417

These figures are also interesting in that they bring out the rather striking fact that the new finder system enables 513 selectors to give the equivalent service provided by 3163 selectors on the uniselector system.

Table II. shows how the saving in number of 1st selectors varies with the calling rate and size of exchange, this saving being of considerable magnitude at the higher calling rates. It may be remarked that these economies in first rank selectors are due to the partial secondary trunking scheme incorporated in the new finder system.

TABLE II.

TU/Sub.	L.F. (200 Pt.)	New Line Fdr. System.		Uniselector System.	
		Sec. Fdrs. (50 Pt.)	1st Sel.	Unisels. (25 Pt.)	1st Sel.
1,000 *Lines.*					
.02	60	10	40	1000	35
.04	90	24	64	1000	65
.06	120	32	92	1000	95
.08	145	38	113	1000	125
.10	175	52	137	1000	156
5,000 *Lines.*					
.02	300	30	180	5000	160
.04	450	80	280	5000	315
.06	600	108	408	5000	472
.08	725	140	515	5000	625
.10	875	207	632	5000	780
10,000 *Lines.*					
.02	600	54	354	10000	315
.04	900	150	550	10000	625
.06	1200	204	804	10000	944
.08	1450	266	1016	10000	1250
.10	1750	396	1246	10000	1560

Conclusion.

It will thus be clear that the line finder system is an important advance in the securing of substantial economies in first cost and upkeep of future automatic exchanges, and also in the giving of enhanced flexibility and improved service. It is of interest to observe that this advance has been secured solely by improvements in the trunking arrangements in conjunction with the adaptation of advanced circuit principles, without resorting to any new form of switching mechanism and that, whilst the new system requires additional two-motion selectors, this increase is much more than off-set by the saving effected due to the elimination of a uniselector from each subscriber's line.

It will be apparent that the present advance has been mainly brought about by the constant efforts that have been made towards standardisation and simplification of automatic telephone apparatus. In the past, the Department's earlier automatic apparatus was successfully adapted in successive stages to meet ever-widening demands, culminating in the huge expansion for Director working on a very large scale. So now, at the present time, the two-motion selector has again been readily adapted to meet new demands, and that with very satisfactory results.

FURTHER PROBLEMS IN AUTOMATIC TRUNKING— SOME INTERESTING SOLUTIONS BY MEANS OF THE CALCULUS.

N. A. Hawkins, A.M.I.E.E.

Outline of Contents.

(*a*) Introduction.
(*b*) Use of Grinsted's Approximation for large groups of selectors.
(*c*) Use of Taylor's Theorem.
(*d*) Determination of $\frac{dB}{dA}$ and $\frac{dB}{dA}$.
(*e*) Applications to determine traffic capacity of groups.
(*f*) Last contact traffic and determination of $\frac{dC}{dA}$
(*g*) Application to practical problems.
(*h*) Conclusion.

(*a*) *Introduction.*

PERSONS engaged in any branch of engineering were, in their student days, introduced to the mysteries of the Infinitesimal Calculus and to its application to electrical and civil engineering. The readers of this Journal will also be familiar with its application to telephone transmission theory, but very few are aware of the uses of the calculus in problems connected with automatic trunking. This is no doubt due to a dearth of well-known literature on the subject.

A number of people now engaged on trunking work have, at various times, asked the author how the values of traffic capacity, used in Post Office design, for cases of full availability have been determined. Since the calculus is applied under certain circumstances it is proposed to indicate briefly the steps taken in determining traffic quantities before its use.

When evaluating Erlang's expression, it has been found simplest to choose a constant value of traffic and by the development of the successive terms in the expression $1+A+\frac{A^2}{2!}+\ldots\ldots\ldots\frac{A^x}{x!}$ to determine the grade of service for various numbers of switches, from the theory

$$\text{Grade of Service} = \frac{\frac{A^x}{x!}}{1+A+\frac{A^2}{2!}+\ldots\ldots\ldots\frac{A^x}{x!}}$$

A and x being the traffic and number of selectors respectively. It will be appreciated that it is not possible to find directly by this means the traffic capacity of a given number of selectors for a given grade of service. For automatic exchange design it is most important that the traffic capacity of a group of selectors for a given grade of service be known. In order, therefore, to determine this from figures obtained when using the above method, Taylor's Theorem is applied; some mention of this theorem will be made under item (*c*) of this article.

(*b*) *Use of Grinsted's Approximation.*

In Part 4, Volume 23 of this Journal, it was stated that Grinsted's approximation to Erlang's theory was most nearly true for good grades of service. The evaluation of the Erlang expression becomes very tedious when the values of total traffic and number of selectors become large and, since for all practical purposes we do not require values resulting in a grade of service worse than approximately 1 in 100, a large amount of the work involved would be unnecessary. Grinsted's approximation is therefore used and is applied by considering a number of selectors sufficiently great, for the given value of traffic, to assume that the value of the grade of service obtained is equal, to a high degree of accuracy, to that which would be obtained when evaluating the Erlang expression. A little practice shows what relation is necessary between the number of selectors and total traffic when the above holds

and it is now proposed to indicate how Grinsted's approximation is applied, by considering a total traffic of 30 traffic units.

It will be remembered that the theory of W. H. Grinsted is Grade of Service $= \frac{\frac{A^x}{x!}}{e^A}$ A, x and e being total traffic, number of selectors and the base of Naperian logarithms respectively.

Now if $A = 30 \log e^A = 30 \times 0.4342945 = 13.0288350 = \log 10686.48 \times 10^9$

Assuming that this theory is sufficiently accurate when $x = 50$ we have,

$$\frac{A^x}{x!} = \frac{30^{50}}{50!} \text{ and } \log \frac{A^x}{x!} = 50 \times 1.4771213 - 64.4830749 = \log 2.360424 \times 10^9$$

From Grinsted's approximation therefore,

$$\text{Grade of Service} = \frac{2.36 \times 10^9}{10686.5 \times 10^9} = 0.000022088$$

To get a closer approximation we can determine the value of $\frac{A^{x+1}}{(x+1)!}$ and therefore from $1 + A + \frac{A^2}{2!} + \ldots\ldots\ldots \frac{A^x}{x!} = e^A - \left[\frac{A^{x+1}}{(x+1)!} + \ldots\ldots\ldots a\right]$ obtain more closely the value of the denominator in the Erlang expression.

$$\text{Now } \frac{A^{x+1}}{(x+1)!} = \frac{A^x}{x!} \times \frac{A}{x+1} = \frac{2.36 \times 10^9 \times 30}{51} = 1.39 \times 10^9.$$

Therefore $\frac{A^{x+1}}{(x+1)!} + \ldots\ldots\ldots\ldots a = 2 \times 10^9$ approximately.

$$\text{Hence } \sum_{x=0}^{x} \frac{A^x}{x!} = 10^9(10686 - 2) = 10684 \times 10^9$$

$$\text{and Grade of Service} = \frac{2.3604 \times 10^9}{10684 \times 10^9} = 0.000022093$$

This now gives a starting point to the evaluation, for by subtracting $\frac{A^x}{x!}$ from $\sum_{x=0}^{x} \frac{A^x}{x!}$ we get $\sum_{x=0}^{x=x-1} \frac{A^x}{x!}$, the denominator in the expression $\frac{\frac{A^{x-1}}{(x-1)!}}{1 + A + \frac{A^2}{2!} \ldots\ldots\ldots \frac{A^{x-1}}{(x-1)}}$, the numerator of which is obtained from $\frac{A^{x-1}}{(x-1)!} = \frac{A}{x!} \cdot \frac{x}{A}$

Hence by successive reduction we can determine values enabling the grade of service for any number of selectors with the given value of traffic offered to be obtained.

By carrying out a number of evaluations of this kind for different amounts of total traffic, a series of values is obtained for the grade of service with different numbers of selectors. If we were to consider any definite grade of service, such as 1 in 500 $= 0.002$, it would be found that, except in very few cases, no direct information would be available as to the number of selectors required to give this grade of service with the given amounts of total traffic. For example, with a total traffic of 30 T.U., 45 selectors will give a grade of service of 0.00232 and with a total traffic of 60 T.U., 80 selectors will give a grade of service of 0.002199. We could find, however, by trial and error what values of total traffic offered to the groups of 45 and 80 selectors respectively which will cause a grade of service of 0.002, but this is a very lengthy process and also unnecessary as shown in the next few paragraphs.

(*c*) *Use of Taylor's Theorem.*

Since it is desired to find what alteration is necessary in the value of total traffic A, when the value B obtained from the expression $B = \frac{\frac{A^x}{x!}}{\sum_{x=0}^{x} \frac{A^x}{x!}}$ is adjusted to meet the required condition for the given number of selectors x, we can say that for the present purpose x is constant and therefore that A is dependent on B or rather B is a function of A. Expressed symbolically $B = f(A)$.

Now Taylor's Theorem can be applied to any case where having given the value of a function for a particular value of the variable, it is required to find the value of the same function for a slightly different value of the variable.

In this case therefore we have,

$$B = f(A) \text{ and } B + \delta B = f(A + \delta A)$$

where δB is the increase in the value of B for an increase of δA in the value of A.

Applying Taylor's theorem this can be expressed as,

$$B + \delta B = f(A) + \delta A\, f'(A) + \frac{(\delta A)^2}{2!} f''(A) + \ldots (1)$$

where $f'(A)$ is the first differential coefficient of $f(A)$ with respect to A and $f''(A)$ is the second differential coefficient of $f(A)$ with respect to A.

If the value of δA is small the value of the third and subsequent terms will be negligible and can therefore be omitted.

Hence $B+\delta B=f(A)+\delta A\, f'(A)$

or $$\delta B=\delta A\, f'(A) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

It will be shown later that the value of $f'(A)$ can easily be determined for any given case. It therefore follows that if either B or A is changed slightly the new value of A or B can be obtained. The above approximation (formula (2)) only applies where δA or δB are small and should greater accuracy be required it is necessary to evaluate the third term in expression (1).

(*d*) *Determination of* $f'(A)$ *and* $f''(A)$.

Considering, firstly, Erlang's theory which has been adopted as standard for Post Office design in all cases of full availability where standard grade of service conditions apply. This theory may be expressed in the form,

$$B=\frac{\frac{A^x}{x!}}{1+A+\frac{A^2}{2!}+\ldots\ldots\ldots\frac{A^x}{x!}}$$

where B is the proportion of lost calls or grade of service,

A is the total traffic offered,

x is the number of selectors in the group.

Then $$f(A)=B=\frac{\frac{A^x}{x!}}{1+A+\frac{A^2}{2!}+\ldots\ldots\ldots\frac{A^x}{x!}}$$

and $$f'(A)=\frac{df(A)}{dA}=$$

$$\frac{\left[1+A+\frac{A^2}{2!}+\ldots\ldots\ldots\frac{A^x}{x!}\right]\frac{xA^{x-1}}{x!}-\frac{A^x}{x!}\left[1+A+\frac{A^2}{2!}+\ldots\ldots\ldots\frac{A^{x-1}}{(x-1)!}\right]}{\left[1+A+\frac{A^2}{2!}+\ldots\ldots\ldots\frac{A^x}{x!}\right]^2}$$

$$f'(A)=\frac{x\cdot\frac{A^{x-1}}{x!}}{1+A+\frac{A^2}{2!}+\ldots\ldots\ldots\frac{A^x}{x!}}-\frac{\frac{A^x}{x!}}{1+A+\frac{A^2}{2!}+\ldots\ldots\frac{A^x}{x!}}+\frac{\left(\frac{A^x}{x!}\right)^2}{\left(1+A+\frac{A^2}{2!}+\ldots\ldots\frac{A^x}{x!}\right)^2}$$

$$f'(A)=\frac{x}{A}\left[\frac{\frac{A^x}{x!}}{1+A+\frac{A^2}{2!}+\ldots\ldots\frac{A^x}{x!}}\right]^2-B+B^2$$

$$f'(A)=B\left[\frac{x}{A}-1+B\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

It therefore follows that

$$f''(A)=\frac{d\,f'(A)}{dA}=B\left[-\frac{x}{A^2}+\frac{dB}{dA}\right]+\left[\frac{x}{A}-1+B\right]\frac{dB}{dA}$$

$$f''(A)=B\left[-\frac{x}{A^2}+B\left(\frac{x}{A}-1+B\right)\right]+B\left[\frac{x}{A}-1+B\right]$$

$$f''(A)=B\left[-\frac{x}{A^2}+\frac{Bx}{A}-B+B^2+\frac{x^2}{A^2}-\frac{2x}{A}+1+\frac{2Bx}{A}-2B+B^2\right]$$

$$f''(A)=B\left[2B^2+\frac{x}{A}(3B-2)-3B-\frac{x}{A^2}+\frac{x^2}{A^2}+1\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

It is also interesting to note the form of the first and second differential coefficients with respect to A of Grinsted's approximation. This, it will be remembered, can be used as sufficiently approximate to Erlang's theory when the grade of service is good and is expressed as,

$$B=\frac{\frac{A^x}{x!}}{e^A}$$

where B, x and A have their usual significance and e is the base of Naperian logarithms.

Then $$B=f(A)=\frac{\frac{A^x}{x!}}{e^A}=\frac{A^x}{x!}\,e^{-A}$$

and $$f'(A)=\frac{df(A)}{dA}=\frac{x!\left[e^{-A}\times A^{x-1}+(-1)\,e^{-A}A^x\right]}{(x!)^2}$$

$$f'(A)=\frac{e-A^x}{x!}\left[\frac{x}{A}-1\right]$$

$$f'(A)=B\left[\frac{x}{A}-1\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Similarly,

$$f''(A)=\frac{df'(A)}{dA}=B\left[\frac{-x}{A^2}\right]+\left[\frac{x}{A}-1\right]\frac{dB}{dA}$$

$$f''(A)=\frac{-Bx}{A^2}+B\left[\frac{x}{A}-1\right]^2$$

$$f''(A)=B\left[\left(\frac{x}{A}-1\right)^2-\frac{x}{A^2}\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Returning to expression (2) it is seen that in the case of Erlang's theory

$\delta B=\delta A\, f'(A)$

and substituting the value of f' (A) from expression (3)

$$\delta B = \delta A.B\left[\frac{x}{A} - 1 + B\right] \quad \ldots\ldots(7)$$

Further, when the grade of service is good, expression (5) is sufficiently accurate and then

$$\delta B = \delta A\ B\left[\frac{x}{A} - 1\right] \quad \ldots\ldots(8)$$

(*e*) *Practical Applications.*

In the first place considering the variation in the value of total traffic for a known variation in grade of service,

Example 1. It is found that when A = 30 and $x = 45$, B = 0.00232 and if it is required to know the value of A when B = 0.002 we have from

$$\delta B = \delta A.B\left[\frac{x}{A} - 1 + B\right]$$

$$\delta B = 0.002 - 0.00232 = -0.00032$$

and therefore

$$-0.00032 - \delta A \cdot 0.00232\ \ \frac{45}{30} - 1 + .00232$$

and $$\delta A = \frac{-0.00032}{0.00232\ (0.50232)} = -.2746$$

To see what error is involved by assuming that the third and successive terms in expression (1) are negligible we have

$$\delta B = \delta A\ B\left[\frac{x}{A} - 1 + B\right] + \frac{(\delta A)^2}{2!}$$

$$B\left[2B^2 + \frac{x}{A}(3B - 2) - 3B - \frac{x}{A^2} + \frac{x^2}{A^2} + 1\right]$$

$$-0.00032 = \delta A \cdot 0.00116538 + \frac{(\delta A)^2}{2!} \cdot 0.00058830737$$

from which $\delta A = -0.2969$

The correct value of A to produce a loss of 0.002 is therefore 29.703 traffic units.

Example 2. In this case it is desired to ascertain what is the effect on the value of B when A is varied slightly

When A = 60 and $x = 80$ B = 0.002199

To find the effect on B when A is increased to 60.5. Then $\delta A = 0.5$. Hence as a first approximation from

$$\delta B = \delta A.B.\left[\frac{x}{A} - 1 + B\right]$$

$$B = 0.5 \times 0.002199\left[\frac{80}{60} - 1 + .002199\right]$$

$$= 0.0010995 \times .3355323$$

$$= .0003689$$

and therefore B will be 0.0025679

To obtain closer accuracy the term $\frac{(\delta A)^2}{2!}\ f''$ (A) must be included. This has the value $\frac{(\delta A)^2}{2!}\ f''$ (A)

$$= \frac{(0.5)^2}{2!}\ B\left[2B^2 + \frac{x}{A}(3B - 2) - 3B - \frac{x}{A^2} + \frac{x^2}{A^2} + 1\right]$$

which becomes $\frac{(\delta A)^2}{2!}\ f''$ (A) = 0.00002504

and therefore a more accurate value of B is

$$B = .0025679 + 0.00002504$$

or $$B = .0025929$$

It will be appreciated that calculations similar to these can be applied in the cases where the grade of service is good by using the simpler expressions deduced from Grinsted's approximation.

(*f*) *Last Contact Traffic and* $\frac{dC}{dA}$

In an article entitled "Problems in Automatic Trunking—Last Contact Traffic" (Volume 23, Part 4 of this Journal), some mention was made of the theoretical determination of last contact traffic and of the uses to which known values of last contact traffic can be applied. An expression was derived showing the value of last contact traffic in terms of grade of service B, total traffic A and number of selectors x and was given in the form

$$\text{last contact traffic} = B\left[\frac{x}{1 - B} - A\right] \quad \ldots\ldots(9)$$

Now last contact traffic = traffic offered to last contact − lost traffic or if C = last contact traffic

$$C = AB_1 - AB \quad \ldots\ldots(10)$$

where B_1 is the proportionate loss at the $(x-1)$th contact.

Differentiating this expression with respect to A we have,

$$\frac{dC}{dA} = A\frac{dB_1}{dA} - A\frac{dB}{dA} + B_1 - B$$

Now $$B_1 = \frac{Bx}{A(1 - B)}$$

and $$\frac{dB_1}{dA} = \frac{A(1 - B)x\ \frac{dB}{dA} - Bx\left[(1 - B) - A\frac{dB}{dA}\right]}{A^2(1 - B)^2}$$

and since $$\frac{dB}{dA} = B\left[\frac{x}{A} - 1 + B\right]$$

$$\therefore \frac{dB_1}{dA} =$$

$$\frac{AB\alpha\,(1-B)\left[\frac{\alpha}{A}-1+B\right]-B\alpha\,(1-B)+AB^2\alpha\left[\frac{\alpha}{A}-1+B\right]}{A^2(1-B)^2}$$

$$\frac{dB_1}{dA}=\frac{AB\alpha\left[\frac{\alpha}{A}-1+B\right]-B\alpha\,(1-B)}{A^2(1-B)^2}$$

$$\frac{dB_1}{dA}=\frac{\alpha}{A(1-B)^2}\frac{dB}{dA}-\frac{B\alpha}{A^2(1-B)}$$

$$\text{Hence } \frac{dC}{dA}=A\frac{dB_1}{dA}-A\frac{dB}{dA}+B_1-B$$

$$\frac{dC}{dA}=A\left[\frac{\alpha}{A(1-B)^2}\frac{dB}{dA}-\frac{B\alpha}{A^2(1-B)}-\frac{dB}{dA}\right]+B_1-B$$

$$\frac{dC}{dA}=\frac{dB}{dA}\left[\frac{\alpha}{(1-B)^2}-A\right]-\frac{B\alpha}{A(1-B)}+B_1-B$$

but $B_1=\frac{B\alpha}{A(1-B)}$ and therefore

$$\frac{dC}{dA}=\frac{dB}{dA}\left[\frac{\alpha}{(1-B)^2}-A\right]-B \quad \ldots\ldots(11)$$

Clearly then if we increase the values of dA, dB and dC above the infinitessimal limit the resulting expression will not be very inaccurate when applied to practical cases. Replacing dA, dB and dC by δA, δB and δC respectively we get

$$\frac{\delta C}{\delta A}=\frac{\delta B}{\delta A}\left[\frac{\alpha}{(1-B)^2}-A\right]-B$$

$$\text{or } \delta C=\delta B\left[\frac{\alpha}{(1-B)^2}-A\right]-B\delta A \quad \ldots\ldots(12)$$

Generally, both B and δA will be small, so that the term $B\delta A$ can be neglected and as a result

$$\delta C=\delta B\left[\frac{\alpha}{(1-B)^2}-A\right] \quad \ldots\ldots(13)$$

This expression can be applied to all cases where the grade of service is reasonably good and where δB is not too large, as will be shown in the succeeding paragraphs.

(g) Application of $\frac{\delta C}{\delta B}$ *to practical problems.*

Example 1. To determine the variation in last contact traffic for any grade of service slightly different from that at which the last contact traffic is known.

Consider the case of 8 T.U. offered to a group of 17 circuits giving a grade of service of 0.002127. It is known that the last contact traffic = 0.019232 T.U. It is required to find the value of the last contact traffic when the traffic has been varied so that the resulting grade of service is 0.002.

From expression (13)

$$\delta C=\delta B\left[\frac{\alpha}{(1-B)^2}-A\right] \text{ where } A=8\alpha-17B$$

$$=0.002127 \text{ and } \delta B=-0.000127$$

$$\text{then } \delta C=-0.000127\left[\frac{17}{(1-0.002127)^2}-8\right]$$

$$\delta C=-0.000127\,(17.072-8)$$

$$\delta C=-0.001152$$

Hence new value of last contact traffic = 0.019232 − 0.001152 = 0.01808

In order to show what accuracy is given we can determine the value of $B\delta A$ for it is known that a grade of service of 0.002 is obtained when a total traffic of 7.95 T.U.* or more correctly 7.946 T.U. is offered to 17 circuits fully available.

The value of δA is therefore 0.054 and the error in assuming that $B\delta A$ is negligible is $0.002 \times 0.054 = 0.000108$, the correct value of last contact traffic being 0.01808 − 0.000108 = 0.01792 or 0.018 T.U. correct to three decimal places.

Example 2. Having given a value of last contact traffic differing slightly from that for a known value of total traffic and grade of service, to determine the grade of service.

Consider the case when $\alpha = 25$, $A = 15$, $B = 0.005011$. Here last contact traffic = 0.05074 T.U. To find the grade of service when the last contact traffic has increased to 0.052 T.U.

$$\text{From } \delta C=\delta B\left[\frac{\alpha}{(1-B)^2}-A\right]$$

$$0.00126=\delta B\left[\frac{25}{(1-.005011)^2}-15\right]$$

from which $\delta B = .000123$

and therefore the new grade of service is 0.005011 + .000123 = 0.005134.

It must of course be borne in mind that to obtain closer accuracy in either of the cases for which examples have been quoted it would have been necessary to determine the value of δA.

(h) Conclusion.

Throughout this article an attempt has been made to indicate not only how the calculus can be applied to the theories upon which plant quantities are determined in Post Office design, but to illustrate

* *This value has been extracted from T.I. 25, Part 12A.*

also how the resulting mathematical deductions can be used in many instances.

It is appreciated that the resulting accuracy is dependent upon the smallness of the given differences, but nevertheless good results have been obtained with comparatively abnormal given conditions.

Such mathematical determinations as these are mainly applicable when finding theoretically what happens when the grade of service changes, but the author has no doubt that with the naturally increasing demands for automatic exchanges and the consequent gain in experience of traffic and its relation to exchange design some further uses will be found for the methods described.

A COMPLETE SOLUTION OF THE WHEATSTONE BRIDGE OR MURRAY LOOP.

THOS. WOODHOUSE, Preston.

IT is the usual practice to solve these bridges by correlating the current values in all their branches and the method is well known. It is tacitly assumed generally that the points on the bridge, where the galvanometer is connected, have been brought to the same potential when no current will flow through the galvo : and the bridge is said to be balanced.

The unknown resistance of any branch except the galvo circuit, see Fig. 1(*a*), may then be obtained from the proportion :—

$$\frac{P}{Q} = \frac{S}{R} \qquad \ldots\ldots(1)$$

It is not essential that the bridge should be balanced in this manner to calculate the resistance of any single unknown branch, which might even be the galvo circuit, and the following method could be adopted. Campbell's Star to Mesh Transformation Theorem postulates that a star of " *n* " rays in a network of conductors can be replaced by a mesh of $\frac{n(n-1)}{2}$ conductors without affecting the conductivity of the whole system.

The mesh formed by the conductors P, Q and G in the bridge network shown in Fig. **1**(*a*) may therefore be replaced by the 3-ray star *p*, *q*, *g* in Fig. **1**(*b*) if

$$Pp = Qq = Gg = \frac{PQG}{P+Q+G}$$

The total resistance between points A and B in Fig. **1**(*b*) is then

$$= g + \frac{(q+S)(p+R)}{p+q+R+S}$$

Substituting for *p*, *q* and *g* to prove the resistance of the bridge

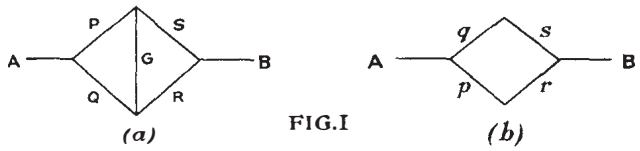


FIG.I

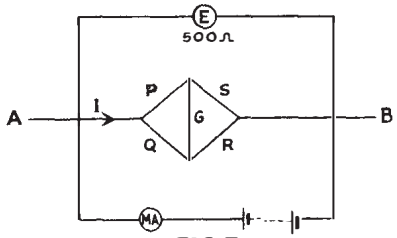


FIG.II

$$= \frac{PQ}{P+Q+G} + \frac{\left\{\frac{G^2PQ}{P+Q+G} + \frac{GPR+GQS+RS(P+Q+G)}{1}\right\}}{\frac{G(P+Q+R+S)+(P+Q)(R+S)}{1}}$$

$$\equiv \frac{G(P^2Q+PQ^2+PQR+PQS)+PQ(P+Q)(R+S)+G^2PQ}{(P+Q+G)\,G(P+Q+R+S)+(P+Q)(R+S)}$$

$$+ \frac{(GPR+GQS)(P+Q+G)+RS(P+Q+G)^2}{\text{L.C.M.}}$$

$$= \frac{(GPQ+PQR+PQS+GPR+GQS)(P+Q+G)+RS(P+Q+G)^2}{(P+Q+G)\,G(P+Q+R+S)+(P+Q)(R+S)}$$

$$= \frac{G(P+S)(Q+R)+PQ(R+S)+RS(P+Q)}{G(P+Q+R+S)+(P+Q)(R+S)} \quad \ldots(2)$$

Any one unknown branch may now be evaluated if the resistance of each of the other four branches is known.

The potential difference between the points A and B, Fig. **2**, should be measured on a high resistance voltmeter, say Detector No. 4, whilst the current flowing into the bridge at A is observed when,

$$I = \frac{E}{\dfrac{G(P+S)(Q+R)+PQ(R+S)+RS(P+Q)}{G(P+Q+R+S)+(P+Q)(R+S)}}$$

from Ohm's Law.

e.g., when E indicates 1 volt and the current through MA = 12 milli-ampères

$$\frac{10}{1000} = \frac{1}{\text{Resistance of Bridge}}$$

whence $R = 100$ ohms.

if P = 100, Q = 1000, G = 100 and S = 10 ohms.

From equation (2),

$$\text{Resistance of Bridge} = \frac{P+Q+R+S}{(P+S)(Q+R)}$$

when G has a maximum value,

and $$= \frac{PQ}{P+Q} + \frac{RS}{R+S}$$

when G is a minimum.

In the particular case where G may have any unknown value between a minimum and maximum it is necessary that the following proposition should exist if the resistance of one other unknown branch is required.

$$\frac{(P+S)(Q+R)}{P+Q+R+S} = \frac{PQ}{P+Q} + \frac{RS}{R+S}$$

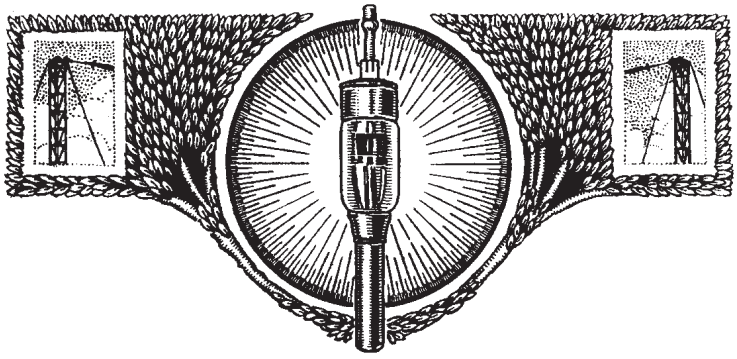
$$\equiv \frac{P}{Q} = \frac{S}{R} \quad \ldots(3)$$

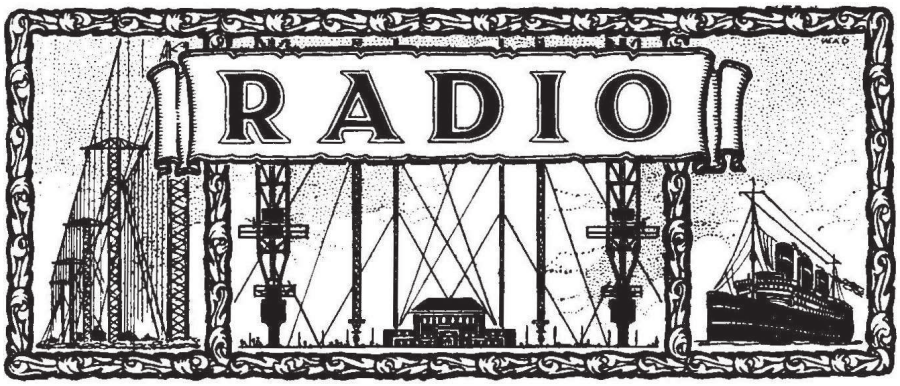
and $R = S$ if $P = Q$.

An identical value for the resistance of the bridge network may be deduced by arranging the sums of the currents meeting at each node as a determinant and proving for the potential difference between the points A and B.

Equation (3) is the condition for balance in the practical case, as stated previously, when no current flows through the galvo; which may be disconnected or short-circuited without affecting the conductivity of the bridge network.

Similar mathematical treatment can be applied to more complicated networks—vide A. Morris discussion of "A New Network Theorem" in the *I.E.E. Journal*, Vol. 63, March, 1925—and it is considered that the solution will prove of general interest.





A CONTINUOUSLY LOADED CABLE FOR USE AT HIGH FREQUENCIES.

F. E. Nancarrow and H. Stanesby.

THIS article describes and gives the results of electrical tests upon a continuously loaded cable developed for use at the Receiving Stations (in this country) of the Long Wave Trans-atlantic Telephony Circuit.

At the Receiving Station many open wire transmission lines are used to convey the energy collected by the various parts of the widely spaced antenna system to the receiver. Here the various portions are passed through attenuating and phase shifting networks before being combined into a single output and fed into the receiver proper. It was conceived that it would be advantageous, both constructionally and electrically, if a cable could be designed to match the impedance of the open wire transmission lines and used for the final termination within the building housing the receiver.

The open wire transmission lines have a characteristic impedance approximating closely to 600 /0° ohms, and hence the problem was to obtain a continuously loaded cable which would have a similar impedance at frequencies in the region of 60 to 70 kc and be suitable for the purpose in view. The maximum length of the cable which it was proposed to use in any one circuit was of the order of 50 yards and hence the attenuation of such a cable was not of primary importance. Messrs. Siemens Brothers of Woolwich submitted a design which met the requirements, and it is this cable which is described.

Description of Cable.—Fig. 1 shows the internal

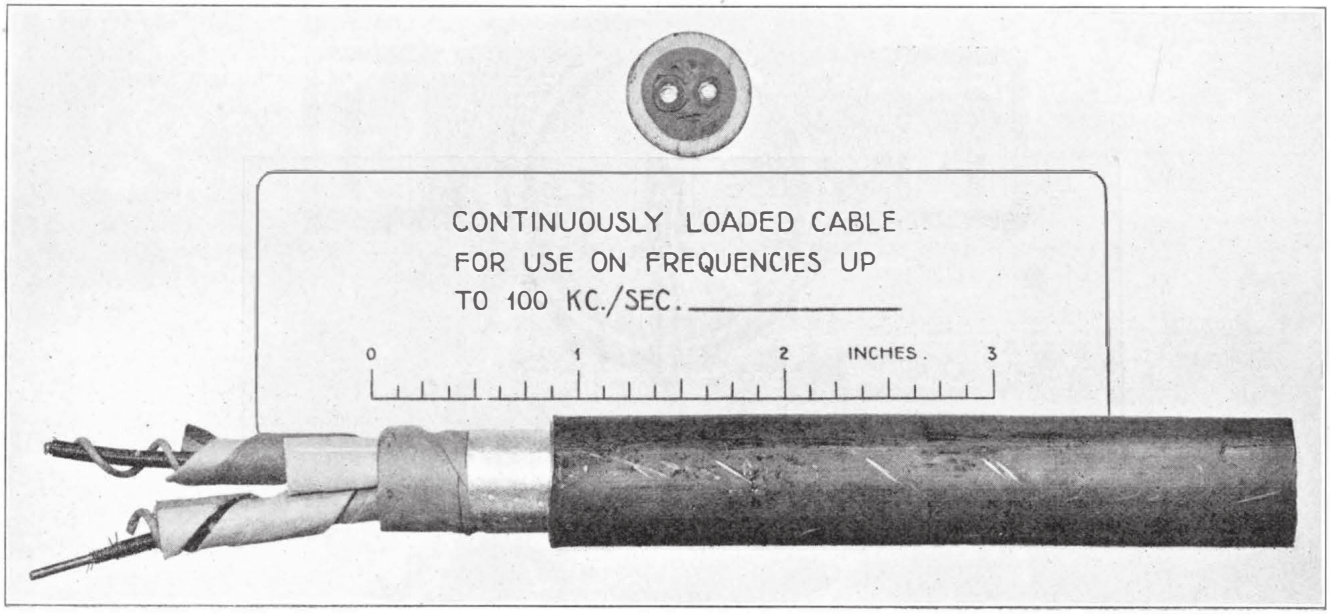


Fig. 1.

construction of the cable. The conductor is of 40 lb. copper wire loaded with two layers of 8 mils diameter unannealed silicon iron wire. Each conductor is air-spaced with a special whipping of string and covered with two layers of paper wrapping. The conductors are then twinned and formed up with the two paper spacers to ensure a round section, and lapped with five layers of paper followed by a final layer of metallised paper which is in contact with the lead sheath. The overall diameter of the cable is 0.62 inch, the sheath having a thickness of 0.08 inch.

Method of Measurement.—The cable was bought in two 1100 yard lengths and tests were carried out on each length at frequencies varying from 20 to 100 kc with certain of the measurements extended to 300 kc. A bridge, constructed in the Radio Laboratory, in which the elements are so screened and connected that the effects of stray capacities are eliminated, was used for the measurements. The impedance at one end of the cable was obtained at various frequencies, first with the far end open-circuited and then short-circuited, and, using this data, the characteristic impedance, attenuation and phase constants calculated from the following relationships :—

$$Z_0 = \sqrt{Z_f Z_c}$$

$$\beta l = \tfrac{1}{2} \text{ arc tanh } \frac{2h \cos \Phi}{1 + h^2}$$

$$\alpha l = n\pi + \tfrac{1}{2} \text{ arc tanh } \frac{2h \sin \Phi}{1 - h^2}$$

where Z_0 = characteristic impedance.

Z_c = impedance with far end short-circuited.

Z_f = impedance with far end open-circuited.

α = phase constant per unit length in radians.

β = attenuation constant per unit length in nepers.

l = length.

n = an integer depending upon the length of the cable.

$h \angle \Phi = \sqrt{Z_c / Z_f}$

Results of Measurement.—The results are given in the table below and are also depicted graphically in Figs. **2**, **3**, **4** and **5**.

SECTION 1.

Frequency Kilocycles/ second.	Characteristic Impedance.	Attenuation constant Nepers/ Mile.	Phase Constant Radians/ Mile.
40	$621.9 \angle 1^0 19^1$	0.455	8.36
50	$573.2 \angle 4^0 48^1$	0.666	10.38
60	$571.1 \angle 2^0 26^1$	0.911	12.4
70	$574.9 \angle 3^0 15^1$	1.194	14.41
80	$574 \angle 2^0 39^1$	1.517	16.39
90	$592.1 \angle 3^0 33^1$	1.84	18.32

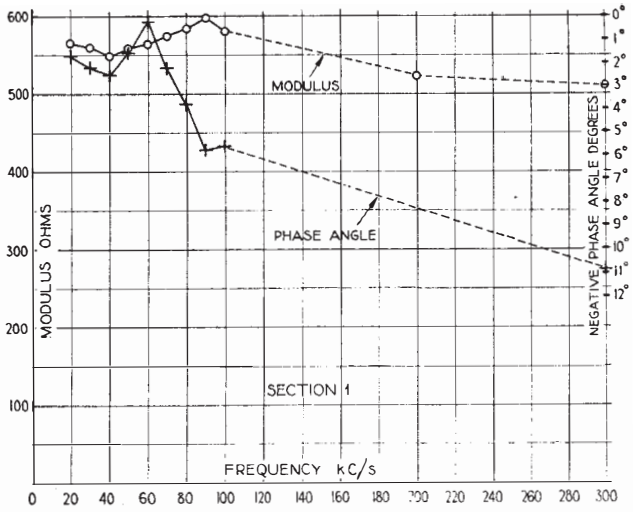


FIG. 2.—VARIATION OF CHARACTERISTIC IMPEDANCE WITH FREQUENCY. SECTION 1.

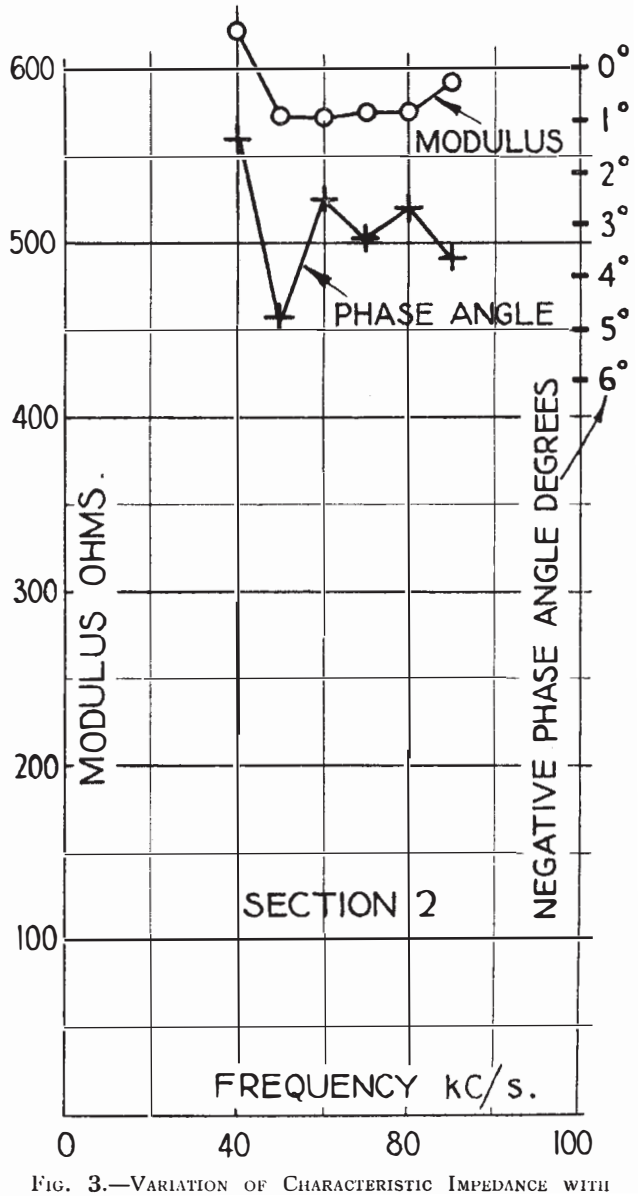


FIG. 3.—VARIATION OF CHARACTERISTIC IMPEDANCE WITH FREQUENCY. SECTION 2.

SECTION 2.

Frequency Kilocycles/ second.	Characteristic Impedance.	Attenuation constant Nepers/ Mile.	Phase Constant Radians/ Mile.
20	$566 \angle 1^{0}43^{1}$	0.160	4.22
30	$559.2 \angle 2^{0}12^{1}$	0.288	6.675
40	$547.8 \angle 2^{0}32^{1}$	0.462	8.40
50	$557.8 \angle 1^{0}32^{1}$	0.675	10.47
60	$562.8 \angle 0^{0}15^{1}$	0.92	12.52
70	$573.4 \angle 2^{0}13^{1}$	1.20	14.54
80	$583.6 \angle 3^{0}45^{1}$	1.51	16.52
90	$596.9 \angle 5^{0}41^{1}$	1.85	18.49
100	$579.7 \angle 5^{0}33^{1}$	2.22	20.28
200	$522.2 \angle 8^{0}8^{1}$	—	—
300	$511.1 \angle 10^{0}56^{1}$	—	—

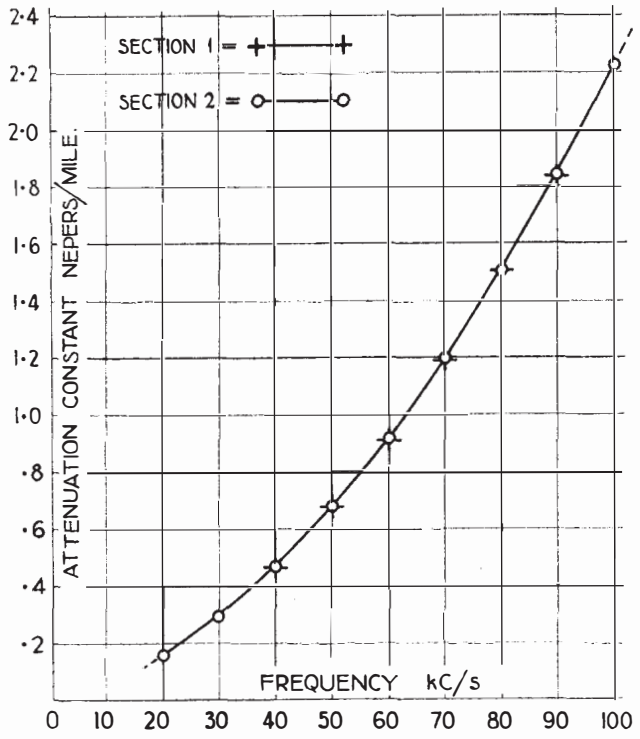


FIG. 4.—VARIATION OF ATTENUATION CONSTANT WITH FREQUENCY.

The agreement in the results for the two sections of the cable, particularly in regard to those for the attenuation constant, demonstrates the utility of the bridge for measurements of this nature.

The irregularity in the characteristic impedance, which is not similar for the two lengths, probably arises from slight variation in the inductance, and hence in the characteristic impedance along the cable, causing internal reflections which manifest themselves as irregularities in the impedance frequency characteristic.

At a frequency of 70 kc the attenuation is 1.2

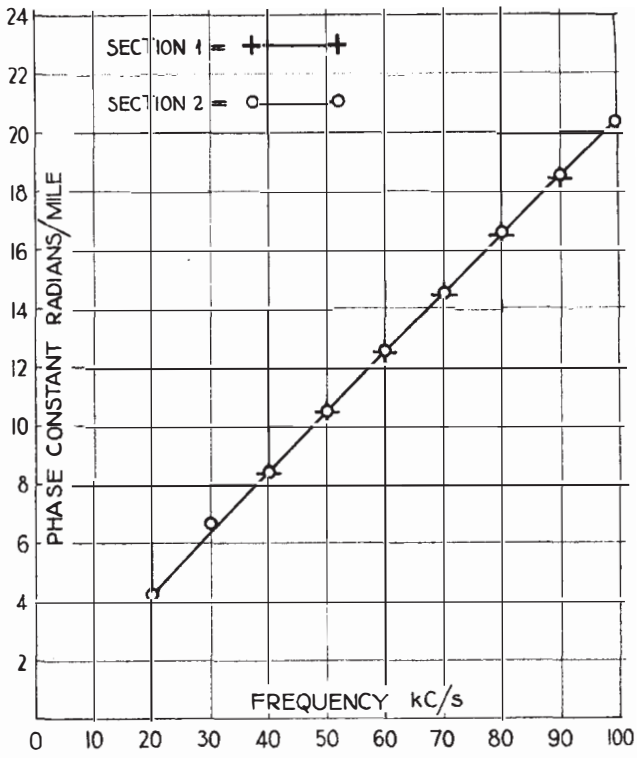


FIG. 5.—VARIATION OF PHASE CONSTANT WITH FREQUENCY.

nepers per mile, so that the interposition of a length of 50 yards into the transmission line circuit would result in a loss of 0.034 nepers (0.3 db). Assuming that this length is terminated at one end by the radio receiver having an input impedance of 600 $\angle 0^{0}$ ohms, then the far end of the cable will present an impedance Z to the open wire transmission line which may be calculated from the expression :—

$$Z = Z_0 \frac{Z_R + Z_0 \tanh P}{Z_0 + Z_R \tanh P}$$

where Z_0 = characteristic impedance of cable.

Z_R = terminating impedance.

P = total propagation constant.

If the values for section 2 of the cable are substituted in this expression Z becomes $607 \angle 2^{0}32^{1}$, a value which approximates closely to the impedance of the open wire line.

Whilst this cable was developed for the particular purpose already described, and affords an interesting example of the application of continuously loaded cable in the realm of high frequencies, it is thought that it may have other applications in the frequency range more familiar to telephone engineers.

One such possible application occurs to the writers of this note, namely, the negotiation of power or water crossings in carrier circuits, whereby the impedance irregularities arising from reflection at the junction points would be avoided by the use of lengths of this type of cable.

THE HEPTODE—A NOVEL THERMIONIC VALVE.

E. J. C. Dixon, A.C.G.I., B.Sc., D.I.C.

A DESCRIPTION was given in recent issues of this Journal* of the apparatus used by the Post Office for generating high frequencies of great constancy for the control of Short-Wave Radio Transmitters. The output from the control equipment is at a low power level and it is necessary to raise the power level to the order of kilowatts before it is radiated at the antenna. It is an essential feature of the high-frequency amplifier that the output power shall have the same frequency as the input power, which implies that the amplifying stages of a short-wave radio transmitter must have no tendency towards self-oscillation. In practice it is difficult to ensure that there shall be no tendency towards self-oscillation, owing to the reactive coupling between the output and the input circuit due to the valve inter-electrode capacity. In a transmitting triode the anode-grid capacity is of the order of 20 $\mu\mu$F, which is comparable in size with the tuning capacities of the circuit. The following notes describe a novel type of valve† which has been designed to overcome the disadvantages inherent in the triode, while taking advantage of the symmetry of the double-acting circuit commonly called the " push-pull " circuit.

The Push-pull Circuit.—The push-pull circuit employs two valves which go through similar oscillation cycles, but with a phase difference of 180 degrees with respect to each other. The two grids are connected to the ends of the input circuit and the centre point is connected to a point of zero potential with regard to the high frequency potentials, usually *via* a bye-pass condenser to the earthed framework of the transmitter. The two anodes are connected in a similar manner to the output circuit, the high tension supply being introduced at the centre point. With a symmetrical lay-out of the circuit components in the screened framework of the transmitter it is possible to balance their stray capacities to earth and thus reduce the number of unknowns in the circuit. A simple push-pull valve would thus consist of a single cathode, two control grids, one on either side of the cathode and two anodes similarly arranged. The cathode would emit in the direction of one anode during one half of the high frequency cycle and towards the second anode during the second half of the cycle. Its dimensions could therefore be the same as those of each of the cathodes in the two triodes which the push-pull valve would replace.

The reaction potential on the first grid from its anode would be in opposite phase to that anode potential and, in order to balance the reaction potential, an equal and opposite potential can conveniently be derived from the second anode, which is 180 degrees out of phase with the first. This can be effected by means of a stabilising grid on the remote side of the second anode and a short cross-connection to the first grid. The capacity of the stabilising grid to the second anode can be arranged to be equal to that between the first anode and grid and the cross-connection may be duplicated in order to reduce its inductance. A complete electrode assembly of this type thus includes seven electrodes

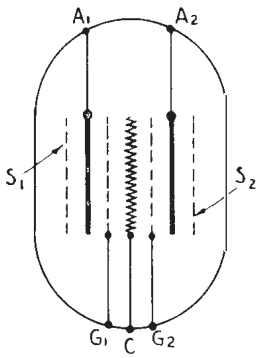


Fig. 1(*a*).

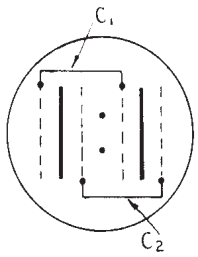


Fig. 1(*b*).

Diagram of Electrode arrangement.

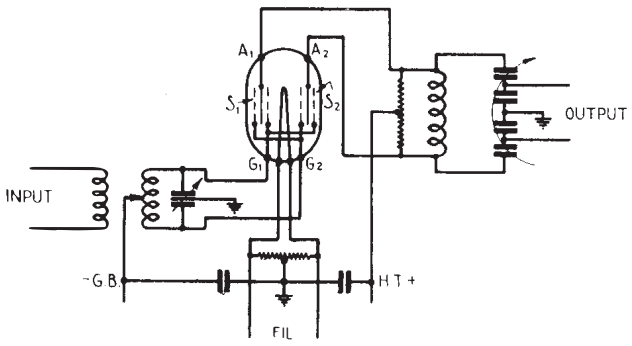


Fig. 2.—Typical Circuit Diagram.

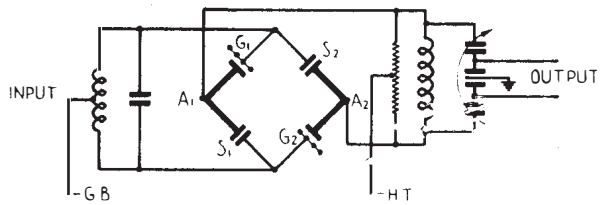


Fig. 3.—Equivalent Bridge Circuit Diagram.

* *Journal P.O.E.E., Vol. 24, Parts 2 and 3.*

† *Brit. Pat. Spec. 352,994. July, 1931.*

—hence the name " Heptode " for the double-acting balanced thermionic valve.

Diagram of the Heptode.—A diagram of the electrode arrangement is shown in Fig. **1***a*, in which C designates the cathode, G_1, G_2 the control grids, A_1, A_2 the anodes and S_1, S_2 the stabilising grids. Fig. **1***b* represents a plan view and shows the cross-connections C_1, C_2.

A typical circuit diagram is shown in Fig. **2**, in which the input is inductively coupled to the grid circuit and the output is capacitively coupled to the anode circuit, while the centre points of both circuits are bye-passed to earth through condensers. To those who are familiar with bridge circuits a comparison of the circuit shown in Fig. **2** with the equivalent circuit shown in Fig. **3** will make the operation of the heptode quite clear.

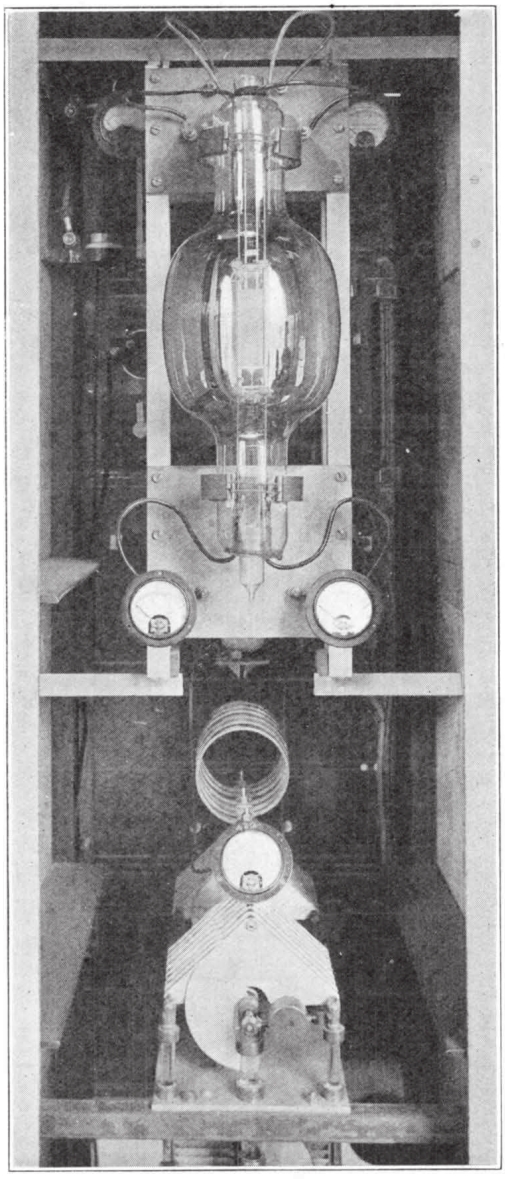


FIG. **4**.—VALVE, THERMIONIC, NO. 63 IN EXPERIMENTAL TRANSMITTER.

Valve Thermionic No. 63.—Considerable experience has been gained by the Radio Section of the Post Office with heptodes of 250 watts dissipation

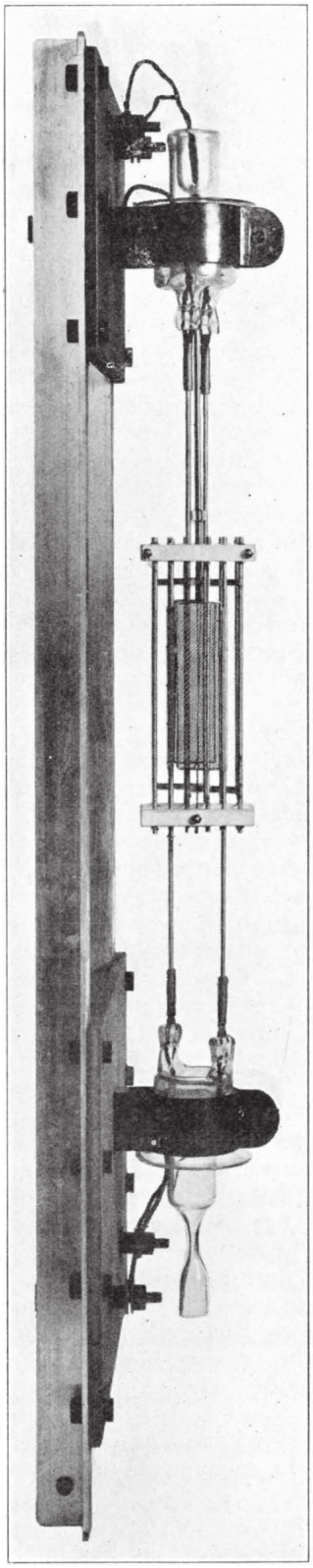


FIG. **5**(*a*).—END VIEW OF HEPTODE ASSEMBLY.

per anode in radiation cooled glass envelopes, both in experimental and commercial circuits at frequencies up to 18,000 kc/sec. A valve of this type (V.T. No. 63) can be accommodated in a rack of standard width and two feet depth, and is usually mounted on a plug-in framework so that it can readily be removed from circuit. Fig. **4** shows the valve, as made by Messrs. Edison Swan Electric Co., in an experimental set-up at Dollis Hill. The valve is shown with the filament and grid seals uppermost and the anode circuit is mounted below the valve. The grid circuit is coupled to the previous stage, which, in this case, is the output of the frequency doubler rack and is screened from the anode circuit. A valve of this type can handle nearly a Kilowatt D.C. input at frequencies of the order of 10,000 kc/sec and is capable of providing sufficient output to excite two triodes, each of 3 kw dissipation, connected in a push-pull circuit.

Design Adjustment and Test.—The most simple form of design is a system of planar electrodes grouped about a loop cathode, and an end elevation of such an assembly is shown in Fig. **5***a*. The electrodes are supported on a series of parallel rods of molybdenum, some of which are extended to form leads and, at the same time, to support the assembly from the glass " feet " which are to be fused to the valve envelope. The assembly is rigidly spaced by bars of a fired insulator known as " lavite," which are in turn rigidly connected together by molybdenum bolts. A front view of the assembly is shown in Fig. **5***b*, in which the filament leads spaced by a lavite insulator, the adjacent grid leads and, at the lower end of the assembly, the anode leads can be distinguished. The side electrodes seen in end-on view in Fig. **5***a* are screens to prevent bombardment of the glass envelope by emission from the filament during the process of evacuation. While these screens affect the distribution of the field around the electrode assembly, they are not essential parts of the balanced system and are only included to simplify the process of manufacture of the valve.

The method of adjustment is to connect the assembly in circuit as shown in Figs. **2** and **4**, apply high frequency excitation to the input and, with H.T. disconnected, measure the circulating current in the output circuit. The size of the stabilising condenser is then adjusted by altering the number of cross-wires in the grids S_1 and S_2 until the out-of-balance current in the output circuit is a minimum. It will be seen that the stabilising grid of the valve shown in Fig. **5***b* has only three cross wires. The assembly is then enveloped, baked and exhausted, and the complete valve can be checked in the same manner as the assembly. A neat method of checking the balance when the electrodes are dissipating energy (" hot balance test ") has been devised by A. J. Symonds, of Rugby Radio Station, and consists of observing the output and D.C. input meter indications for values of anode tuning condenser near the point of resonance. For a perfectly balanced system the maximum output reading will coincide with the minimum input reading, while for unbalanced systems the maximum and minimum readings will be displaced along the tuning condenser scale. Fig. **6** shows typical balance curves and gives criteria for estimating whether the stabilising capacity is too small or too great. The practical test applied to high-frequency amplifying stages is

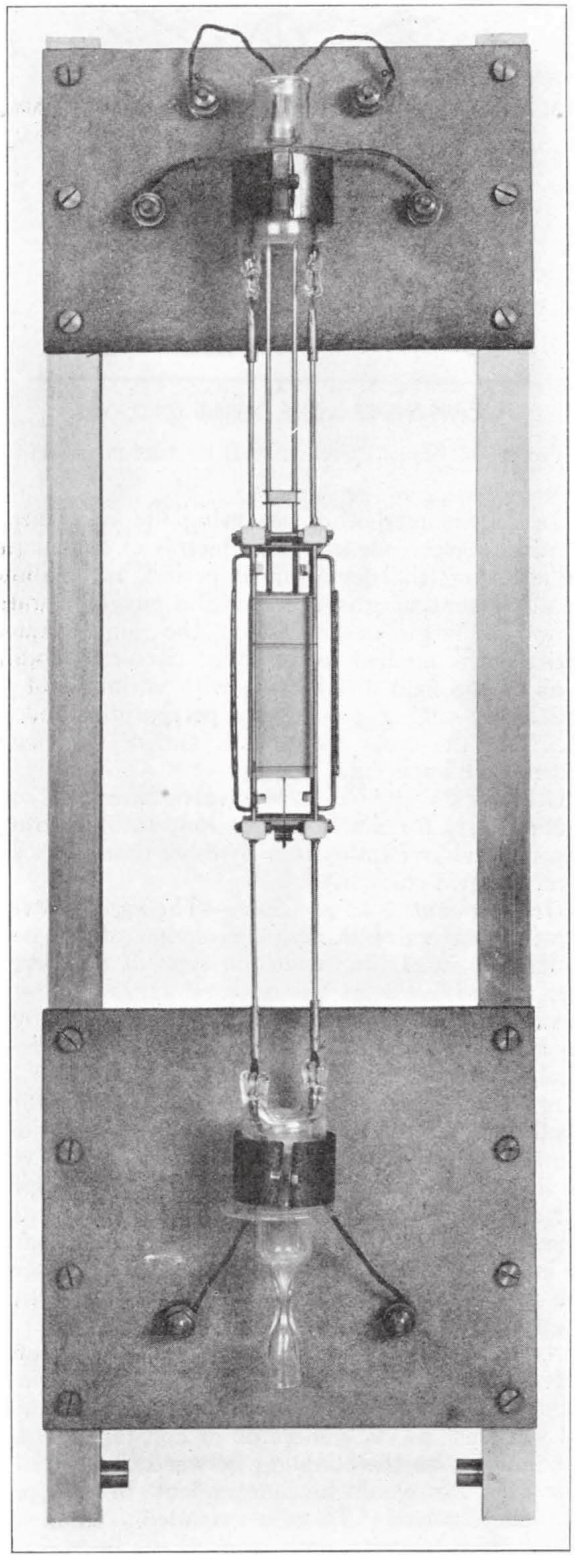


FIG. 5(*b*).—FRONT VIEW OF HEPTODE ASSEMBLY.

to apply the H.T. without the grid excitation and reduce the grid bias voltage to zero. The stage should not self-oscillate at any setting of the grid and anode tuning condensers.

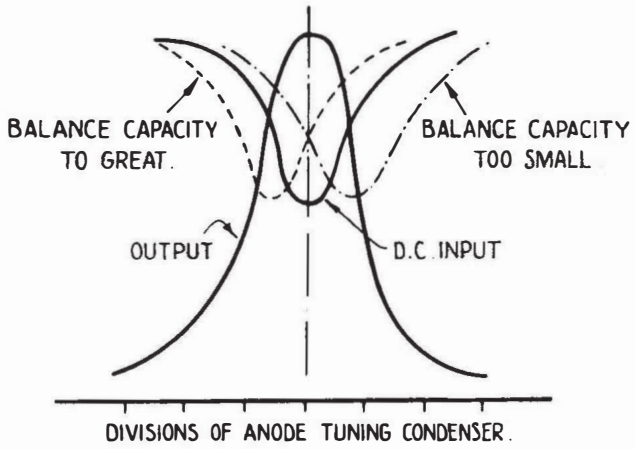


FIG. 6.—BALANCE CURVES FOR H.F. AMPLIFYING STAGE.

An elegant method of observing the field distribution in the electrode system, which is of considerable value during the development period, is to allow a small amount of gas to enter the envelope until a glow discharge occurs when the high-frequency excitation is applied to the input circuit. Modifications of the field distribution with variation of grid and anode tuning are readily perceptible and the effects of the cross-connections and of the electron screens are apparent.

Other tests applied to the valve are the usual routine tests for filament emission, static characteristics (which must not differ by more than 12½%) and reversed grid current.

Development to larger sizes.—The logical development of the valve is in the direction of the cooled anode in insulating envelope type of construction and two different techniques are suggested by the metal tube in silica envelope valves, and by the de-mountable valves constructed of porcelain and steel. Neither of these techniques, however, has progressed to the stage at which it could readily be applied to the design of a heptode and experiments are limited at the moment to radiation cooled valves in silica envelopes of about one kilowatt dissipation per anode. A valve of this type, constructed by Messrs. Mullard Radio Valve Co., is shown in Fig. 7, in which it will be noted that no electron screens are necessary owing to the refractory properties of the silica envelope.

Applications of the Heptode.—The use of the valve has been described only for radio transmitter amplifying circuits, but it has also considerable possibilities as a generator of constant frequency oscillations, as the coupling between the output and input circuits would be independent of the valve. Its field of use might also be extended to small valves in receiving circuits, but the possibilities in this direction have yet to be investigated.

An alternative and well-known method of preventing back coupling in amplifying valves is by the use

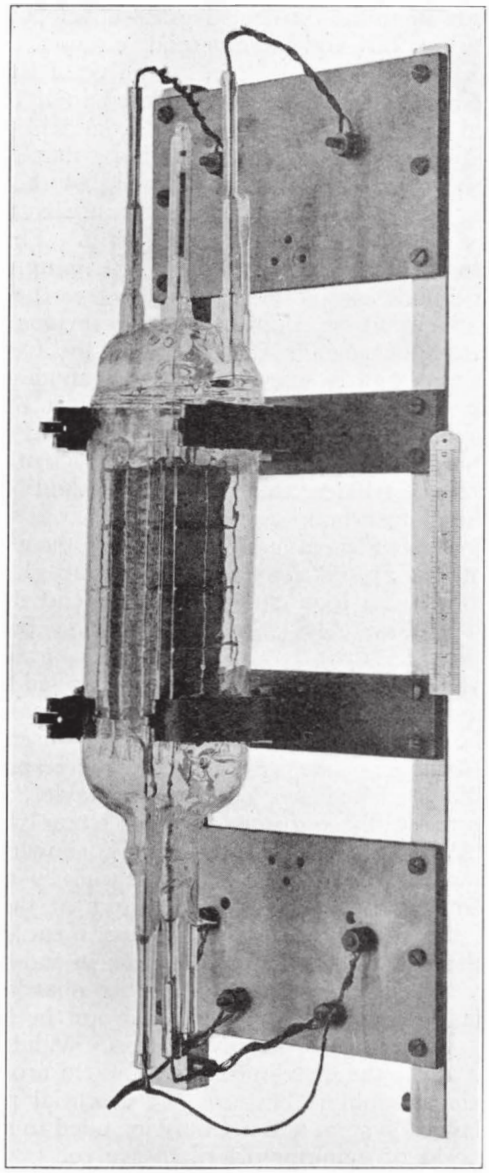


FIG. 7.—S.V 2000—EXPERIMENTAL HEPTODE IN SILICA ENVELOPE.

of a screening grid between the control grid and anode of an ordinary triode. This method finds large application in receiving valves and it is also used to some extent in transmitting valves. The development of large-sized screened grid transmitting valves is still in progress, but such valves possess one inherent disadvantage in that the anode impedance is necessarily very high. The heptode on the other hand has the same latitude in anode impedance as a simple triode, and it is possible to construct such valves with relatively low impedance. To obtain an efficient circuit it is essential that the impedance of the anode circuit external to the valve should be of the same order as the internal impedance of the valve. On long and medium waves it is possible to obtain this order of impedance in the anode circuit, but on short waves this is impossible, and it is on such wave-lengths that the heptode is likely to find its most useful application.

NOTES & COMMENTS

HISTORY OF THE POST OFFICE ENGINEERING DEPARTMENT.

THE Council of the Institution of Post Office Electrical Engineers has had under consideration the question of arranging for the compilation of a History of the Post Office Engineering Department, but came to the conclusion that it was not possible to undertake such a task at the present time. The Council feels, however, that it would be very unfortunate if information of historical value which is at present available should be lost merely through the lack of any organisation for the collection of such valuable literary material. The Council wishes to announce, therefore, that it has decided to arrange for the filing and indexing of any memoirs or information of historical value which may be offered to the Institution.

The Council would be glad to hear from any reader who may be in possession of documents of the nature referred to which he considers would be of historical value or if he would be good enough to write a few notes on any particular question of historical interest with which he may have been associated. The period in regard to which information is most valuable is that preceding the publication of the P.O.E.E. Journal, *i.e.*, prior to 1908.

At the present time any document or record in connection with the life and work of Samuel Alfred Varley would be welcomed. Varley was active in the electrical world during the 1870 period and if any reader is in possession of any item of personal or historical interest regarding Varley the Secretary would be glad to hear from him.

Communications on this subject should be addressed to :

The Secretary,
Institution of P.O. Electrical Engineers,
Engineer-in-Chief's Office, G.P.O.,
Alder House, London, E.C.1.

MR. A. J. STUBBS.

Readers of the Journal will be interested in the announcement that Mr. A. J. Stubbs was ordained at Rochester Cathedral, on the 20th December, as curate of All Saints Church, Chatham. Mr. Stubbs is now seventy years of age and one feels considerable satisfaction in hearing of at least one case of a pensioned officer who has distinguished himself in another sphere. He is being presented with an album signed by the 329 subscribers who combined in a presentation of a cheque from the congregation of Woodside Parish Church, Croydon, which Mr. Stubbs has served for nearly a quarter of a century as lay reader and churchwarden.

BACK NUMBERS OF JOURNAL.

Offers are made occasionally by retiring members to dispose of their sets of the Journal. The Editor will be pleased to record the names of any members who desire to avail themselves of such offers.

TRANSMISSION UNITS SCALE.

Messrs. Siemens Bros. has asked us to announce that the Scale giving the relationship between the Units generally used in Telephone Engineering, which appeared on page 259 of the October issue, can be obtained from them in the form of a blotter.

AGNER KRARUP ERLANG.

With the growth of automatic telephony and the consequent increase of interest in trunking problems, the name of Erlang has become familiar to readers of this Journal. It may perhaps be of interest, therefore, to give a little information regarding the actual personality behind this name.

Erlang was born in 1878 and entered the service of the Copenhagen Telephone Company in 1909. His speciality was the use of probability calculations on telephone problems and his work on this subject has been translated into many languages. His principal contribution to this field was the development of a theory for the traffic capacity of circuits when the actual number of circuits available is

AGNER KRARUP ERLANG.

restricted. The expression which he obtained by the method of statistical equilibrium for this case is quite simple and forms the basis of the design curves used by the British Post Office.

Erlang also acquired a reputation as a constructor of measuring instruments for audio frequencies and was the author of an essay dealing with the theory of telephone cables published in the Danish Journal "Elektrotekniren," in 1911. Other publications of Erlang's are :—

Calcul des probabiltiés et conversations téléphoniques. Revue Générale de l'Electricité t XVIII, p. 305, Paris, 1925.

New Alternating Current Compensation Apparatus for Telephonic Measurements. Journal of Inst. of E.E., 1913, Vol. 51, page 794.

Etude théorique élémentaire sur le Transformateur d'un Appareil Téléphonique. Vie Technique et Industrielle, Oct., 1927.

How to reduce to a Minimum the Mean Error of Tables. The Napier Tercentenary Memorial Volume. Royal Society of Edinburgh, 1915.

Solution of some Problems in the Theory of Probabilities of Significance in Automatic Telephone Exchanges. The Post Office E.E. Journal, 1918, p. 189.

Lösung einiger Problems der Wahrscheinlichkeitsrechnung von Bedeutung für die selbsttätigen Fernsprechämter. Elektrotechnische Zeitschrift, 1918, Heft 51.

Solution de quelques problèmes de la théorie des probabilitiés présentant de l'importance pour les bureaus téléphoniques automatiques. Annals des Postes, Télégraphes et Téléphones, Nr. 4, Juillet-Août, 1922. (See also Appendix to a paper of G. F. O'dell: The influence of traffic on automatic exchange design. 1920. Professional Paper No. 85).

Calcul des probabilités et conversations téléphoniques. Revue Générale de l'Electricité t XX, p. 270, Paris, 1926.

Application du calcul des probabilités en Téléphonie. Annales des Postes, T. et T. Nr. 7, Juillet, 1925.

Démonstrations de la loi Maxwell, proportion fondamentale de la théorie des gaz. Le Vie Technique et Industrielle, Mai, 1926, p. 72.

Some Applications of the Method of Statistical Equilibrium. 6th Congress of Mathematicians, Copenhagen, 1925.

Quelques applications de la méthode de l'équilibre statistique dans la théorie des probabilités. Anales des Postes, T. et T. Sept., 1928.

Mr. Erlang died on the 3rd February, 1929, after an operation and a few days' illness.

While Erlang made such striking contributions to Telephony, he was a man of charming personality and of extremely modest bearing. His death at such an early age is to be widely regretted.

ECONOMY 60 YEARS AGO.

By the courtesy of Mr. A. B. Gilbert the Board of Editors has obtained a number of extracts from the minutes of a Conference of Engineers of the Northern Division held at York in July, 1872. The extracts have such an up-to-date application that the Board feels that readers will appreciate some notes regarding them. Lack of space prevents their complete publication.

Apparatus.—It may seem odd at this date to read of a choice having to be made between double current Morse instruments and Direct Sounders or Writers, but the evidence shows that problems in economics were not considered as being outwith the scope of the Engineering Department of that period. This is further exemplified by the references to the measures taken to effect savings in the number of cells required on circuits. The efforts resulted in the saving of 4300 cells.

Open Lines.—The conference dealt with such matters as the following :—

The necessity for measuring lines with a view to the setting up of reliable records of the plant.

The numbering of poles and marking them to show the year of erection.

The frequency of line inspections. Linemen to walk main routes once per week and immediately after storms; loops and spurs and offices at intervals of not less than two months.

That no larch poles be painted unless the Department be compelled to do so by Public Bodies or private individuals having control of the roads.

Method of paying gangs.

Uniforms and Satchels for Linemen.

Report forms *re* Survey of Offices and road lines.

Revision of Inspectors' Sections and Linemen's lengths.

Tools.—Complaint is made of the quality and unsuitability of the tools supplied. The result of experiments with Marshall's Patent Borer, Digger

and Spanish Spoons is referred to. The Digger was a failure, but the Borer and Spoons appear to have found considerable favour.

These references indicate very clearly that " Bar and Spoon " methods were early to the fore and the knowledge of the Department's return to them under present day conditions would no doubt gladden the hearts of the 1872 conference.

Cost of Works.—" That the estimates of Costs of Works upon which the Works Orders are based shall not be exceeded without in the first instance an addendum having been obtained authorising the further expenditure."

The extracts unfortunately do not state the number of the T.E. form referring !

Week-end Leave.—Permission was given to Foremen of gangs to use a railway warrant to return to their Headquarters on the Saturday evening and to report for duty at the appointed time on the Monday morning.

There is no reference to the first available train !

W. M. CROWE.

William Miller Crowe, the Chairman and Managing Director of Ericsson Telephones Limited, has retired from 1st October, although he will still retain a seat on the Board of Directors. Mr. Crowe has been with the British Ericsson Company from its inception thirty-three years ago and for twenty-one years has been Chairman and Managing Director. He commenced his London career as Manager for the famous Mr. Edison when the phonograph was first brought to this country in 1892. Six years later he was appointed Manager in London for Messrs. Ericsson, of Stockholm, the well-known telephone manufacturers, whose business in this country at that time was chiefly with the National Telephone Co. In 1903 a private company was formed to take over the factory at Beeston, Notts., owned by the National Telephone Co.—the latter retaining one-half interest.

In 1911 the Post Office took over the National Telephone Co., and then a public company was formed by Ericssons to take over the complete factory, since which time the Company has gone on from success to success.

NEW MEASURING INSTRUMENTS.

Messrs. Elliott Bros. are about to place on the market a new series of measuring instruments which should well meet demands long felt. The first is a Frequency Indicator for use on " Standard Frequency " circuits. The calibration is 48 to 52 periods and the apparatus is fitted with an 18" scale and the pointer has a swing of 200 degrees, the scale being divided in tenth periods, each tenth occupying nearly ½" on the scale. It is thus possible to read accurately and easily to 1/10th period, and to estimate very much lower. The instrument operates on induction principles, with opposing resonant circuits tuned to fine limits, and is said to be practically free from wave form and temperature errors. A modified pattern can be used as a recording instrument with a pen movement which has an inappreciable time lag.

The other two instruments are for the purpose of measuring currents in links in distribution boxes and in fuses in feed pillars. The principles of the two pieces of apparatus are the same, the link or fuse being temporarily enclosed in a hinged iron circuit, the jaws of which are opened by a pair of insulated handles. Two opposing transformers are fitted at the pivot ends of the jaws and are connected to a D.C. moving coil indicating instrument which is fitted with a Westinghouse metal oxide rectifier. The instrument has two ranges with suitably marked terminals. The whole outfit weighs only a pound or two. The Link measuring set can be used also for determining the direction of current in the link—from the supply to the load, or vice versa, as sometimes happens. This is accomplished by the use of an additional contact rod, for tapping on to the neutral, connected to a special capacity terminal on the instrument. An increase in deflection indicates that the current is passing through the link in the direction of the arrow marked on the transformer, a decrease the reverse.

TRANSPORT SECTION.

In last issue and also in the Staff Changes given at the end of this number the names of officers transferred and promoted to this new engineering section appear. We take the opportunity of welcoming these officers to the engineering side and trust that not only will they join the Institution and support the Journal, but also contribute to its pages. Motor transport has become an integral part of the Engineering Department organisation and we shall be pleased to lay our pages open for articles dealing with this important branch of the service.

YOUNG PEOPLE'S OWN TELEPHONE EXHIBITION.

An instructive exhibition is being held in the Indian Hall of the Imperial Institute from the 5th to the 23rd January, 1932. Although primarily arranged for young people, the exhibition deals with every phase of communication engineering, and should prove of the greatest benefit to everyone interested in the science. Admission to the exhibition is free.

HEADQUARTER'S NOTES.

EXCHANGE EQUIPMENT.

The following works have been completed :—

Exchange.	Type.	No. of Lines
Tile Hill	New Auto	200
Sheldon (Birmingham)	,,	300
Folkestone	,,	2200
Bristol Central	,,	5030
,, North	,,	1990
,, South	,,	970
,, West	,,	3290
,, Bedminster	,,	875
,, Easton	,,	1485
,, Kingswood	,,	565
,, Stoke Bishop	,,	515
,, Westbury	,,	1080
,, Whitchurch	,,	80
Rottingdean	Auto Extn.	70
Leeds	,,	800
Brighton	,,	2320
Edgware	,,	1500
Colchester	,,	Observation Equipt.
York	,,	Re-arrangements
Coventry	,,	,,
Dorchester	New Manual	540
Staines	,,	1460
High Wycombe	,,	2000
Palmers Green	Manual Extension	800
Northampton	,,	Observation Equipt.
Kilmarnock	,,	240
Norton Grinding Wheel, Newcastle-on-Tyne	P.A.B.X.	30
British Tube Mills, Smethwick	,,	30
McIlroy, Ltd., Reading ...	,,	30
Crane Bennett (London) ...	,,	30
Newcastle-on-Tyne Police ...	,,	30
Nusenbaum, Ltd., Newcastle-on-Tyne	,,	20
Southend Corporation	,,	40
Northern Aluminium, Oxford	,,	30

Orders have been placed for the following :—

Exchange.	Type.	No. of Lines.
Sutton Coldfield	New Auto	1700
Stechford	,,	800
Priory	,,	900
Preston (Torquay)	,,	600
Acocks Green	,,	1800
Kensington	,,	8800
Gerrard	,,	Main Frame
Terminus	,,	4480
Aston Cross	,,	2600
Acomb—York	,,	300
London Trunk (4th Floor Annexe)	,,	Positions
Urmston	,,	Power Plant
Churston	,,	,,
Horsforth, Leeds	,,	,,
Sutton Coldfield	,,	,,
Bury & Darwen	Auto Extn.	Observation Equipt.
Bolton & Rochdale	,,	,,
Farnworth	,,	Observation Equipt.
Bermondsey	,,	Voice Frequency
Fulham	,,	,,
Sloane	,,	,,
Temple Bar	,,	,,
Welbeck	,,	,,
Leeds Central	,,	Additional Selectors
Southampton No. 4	,,	Manual Board
Bermondsey	,,	Toll Control
Hereford	,,	Manual Board
Welbeck	,,	Toll Control
Cosham	,,	200
Hartlepool	,,	210
Four Oaks	New Manual	960
Elmbridge	,,	4180
Ashtead	,,	640
Uxbridge	,,	Power Plant
Wisbech	,,	720
Bury St. Edmunds	,,	780
Burnham	,,	540
Slough	Manual Extension	Observation Equipt.
Windsor	,,	,,
Beaconsfield	,,	,,
Thackery & Co., Leeds ...	P.A.B.X.	30
Daily News, London	,,	40
Berkshire County Council ...	,,	30
Phillips J. & N. (M/R) ...	,,	Re-arrangements
Applin & Barrett, Yeovil ...	,,	30

Two new systems of automatic working are being tried experimentally in London and the Provinces. The Standard Telephones & Cables, Ltd., have developed a scheme known as the " Bypath " system which will be adopted at Bethnal Green and Burton-on-Trent; the latter includes two satellite Exchanges.

The Automatic Telephone Manufacturing Company are installing at Arnold (Wembley) and at Wigan, two new telephone exchanges incorporating their " Strowger Common Control " system.

The Bypath and Common Control systems were described in the July issue of the Journal. It is hoped that the Exchanges concerned will be completed and brought into service early in 1933 and it will, of course, be necessary to observe the behaviour of apparatus under practical conditions for some considerable period before individual performance can be judged and a verdict given as to the merits of either system.

Retirement of Mr. R. Halton.

With the retirement of Mr. R. Halton from the Engineering Department of the Post Office, on the 4th November, the Department has lost one of its most energetic and painstaking officers.

Mr. Halton entered the Post Office Service in the Manchester Telegraph Office in 1886 and was transferred to the Engineering Department at Manchester in 1894, then under the charge of Mr. John Doherty. In 1900 he was promoted to an Engineership in the Ipswich Section and during the following nine years was actively engaged in the general development of that area.

In 1909 Mr. Halton was transferred to the Telegraph Section of the Engineer-in-Chief's Office and after two years was appointed to the position of Executive Engineer, Birmingham.

With the formation of the South Midland District in 1912 he was placed in charge of the Technical Section at Reading. During the War period he was very largely occupied in meeting the requirements of the Fighting Services. With a Naval Base at Portsmouth, an important transport base at Southampton and numerous training camps within the District, the time proved a strenous one and as will be realised there were no fixed hours of duty.

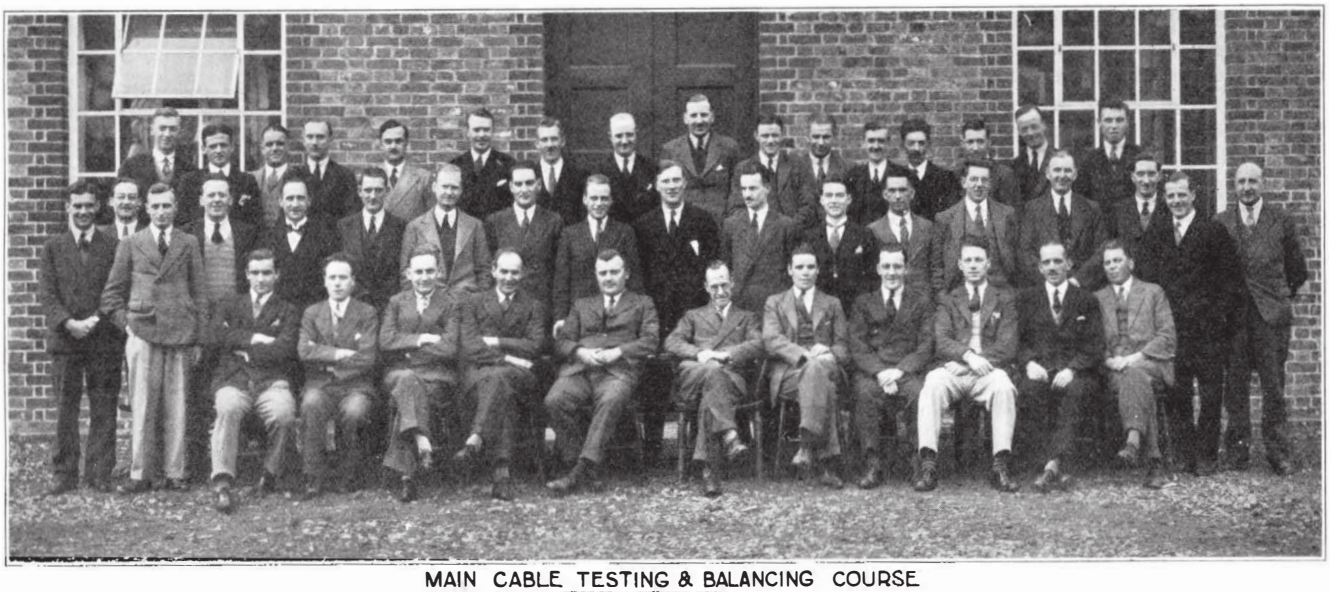
Up to 1928 Mr. Halton was engaged in the telephone development of the District from both a Main and Local point of view and was largely concerned in the successful laying of the London-Southampton-Portsmouth and the London-Bristol Main Backbone Cables.

In 1928 he received his last Departmental reward of efficient service in promotion to Assistant Staff Engineer Lines Section in place of the late Mr. Walter E. Twells. In addition to the supervision of the normal work of the post Mr. Halton performed yeoman service in completing a valuation of all items included in a new Inventory of Line Plant and in this he leaves a record of his work which will remain for many years to come.

Always cheery and ever ready to draw upon his fund of extensive experience to help a colleague, Mr. Halton has, in addition, been associated with several matters of great importance to his colleagues in connection with Salaries, Status and other Service questions. He served on the Executive Committee of the Society of Post Office Engineers for a number of years and held the position of Chairman for three years.

Mr. Halton appeared as a witness before the Industrial Court in 1926 when the case for Executive and Assistant Engineers was presented. This work involved a great amount of self-sacrificing labour on the part of Mr. Halton--willingly given on behalf of all his colleagues.

Our best wishes go to him on his retirement.



MAIN CABLE TESTING & BALANCING COURSE
7TH SEPT - 28TH NOV 1931

H. Hartshorn, Leicester; J.A. Ditchfield, Blackburn; W. Clarke, Preston; A.G. Coates, Oxford; R.W. Hale, York; A.E. Tongcross, Derby; P.G. Bigwood, Stoke-on-Trent; M. Brook, Bradford; S.W. Smith, Bradford; J.W.H. Boon, Newcastle; J. Qean, Newcastle; J. Bingham, Newcastle; W.M. Kendrick, Edinburgh; H.A. Bay, Oxford; F.P. Fable, Guildford; C.H.J. Fleetwood, School Staff;
E.H. Seymour, London; L.F.J. Brunsdon, Guildford; G.R. Sudell, Sch. Staff; W. Batchelor, Dundee; R.A.A. Freshwater, London; T.A. Marks, Guildford; A.T. Stovold, Brighton S; H.V.G. Davies, Bournemouth; A. Lee, London; A.G. England, Birmingham; G.E.H. Body, Plymouth; C.D. Scrafton, Newcastle; W.E.C. Roberts, Plymouth; R.E. Robins, Reading; A.G. Veneer, Brighton S; W.O.L. Goodwin, Canterbury W; F.T. Loveland, Canterbury W; C. Baldey, Canterbury W;
J.H. Broadhurst, Canterbury E; E.P. O'Neill, Glasgow; G.A. Yates, Nottingham; W.T. Palmer, E-in-C Lecturer; S. Mantford, E-in-C Lecturer; G.W. Hodge, E-in-C Lecturer; G.T. Crabb, Liverpool; E.W. Leftsome, Glasgow; J. Gerard, Liverpool; F.A.E. Janks, Brighton N; T.P. Steel, York.

CABLE INSTRUCTIONAL COURSE AT DOLLIS HILL.

A course in Cable Balancing and Precision Testing was held at Dollis Hill Research Station commencing September the 7th, 1931.

The Course lasted 12 weeks, and was attended by 40 members of the Department's Staff, representative of England, Scotland, Wales, and Northern Ireland.

The first fortnight was devoted to a series of lectures by Mr. W. T. Palmer upon suitable Elementary Mathematics and A.C. Theory. An innovation was the introduction of an examination at the end of this fortnight's work, and the 40 officers mentioned above were the survivors of this ordeal—a three hours' paper consisting of 12 questions on Mathematics and Electricity.

All officers attending were either of Inspector rank, or were Skilled Workmen graded as Acting Inspectors for the duration of the Course.

Three weeks were spent in lectures by Mr. G. W.

Hodge on the methods of measuring capacity unbalances in underground cables and of making selections. Mr. Hodge also gave very lucid explana- of the methods of rebalancing cables and of actual cable design and manufacture.

By the courtesy of the Standard Telephones and Cables, Ltd., parties of students were able to visit the North Woolwich works of that firm to see cables and loading coils in various stages of manufacture.

A fortnight was also spent in carrying out balancing work, using both the Double Bridge and the 15 Position Testing Switch and in wrestling with actual selections—the latter being from Mr. Hodge's repertoire.

Mr. W. T. Palmer again took over the class for the last five weeks, during which time four weeks were spent in consideration of the subject of Precision Testing of cables for fault localisation, including the latest A.C. methods and the study of Impedance frequency curves.

A week's practical work was spent in the Laboratory, when particular attention was given to the Murray and Varley tests for incipient faults.

During the weeks in the Lecture Hall many practical examples were worked out by the class, and a number of interesting slides and films were shown.

The officers attending the course had ample opportunity for discussion and exchange of views both between themselves and with members of the E.-in-C's Headquarter's Staff.

This in itself should help greatly in the matter of co-operation, and should be of undoubted help to those attending the Course when carrying out their duties in the future.

In addition, all felt at the conclusion of the Course, that they had gained a broader outlook and a greater understanding of the working of the Department.

The termination of the Course was marked by a convivial evening which embraced a visit to a Variety Theatre and a supper at a neighbouring hostelry, the lecturers and all members of the class being present.

Accompanying this article is a photograph of the lecturers and members of the class who attended this Course.

Unfortunately, Mr. J. L. Winter, of Belfast, Northern Ireland, who also attended, was inadvertently omitted from this group.

A. G. Coates.

Commendable Conduct in Emergencies.

From time to time one hears, often quite incidentally, of creditable conduct on the part of Engineering Department's workmen in difficult, and sometimes dangerous emergencies. It generally happens that the occasion demands a clear perception of the preventive or remedial measures which are necessary; instant action is usually imperative; hesitation means ruin, and, not infrequently, courage and endurance are required either to save the plant or to maintain the service.

In two recent cases the men concerned have received the appreciation and commendation of the Engineer-in-Chief for their conduct. These are but examples of the kind of good work which emergencies seem always to call forth and which, happily, the men themselves are content to regard as "all in the day's work." It is proposed to chronicle such cases in the Journal as they come to hand.

Southampton Section.

Men concerned.

G. T. Fenner, Acting S.W.I.
H. O. Lewis, S.W.II.
W. Palmer, S.W.II.
R. W. Smith, U.S.W.
L. Doswell, Labourer.

Action.

On 4th August, these men successfully sealed or wrapped up joints in manhole when latter was flooded by sudden inrush of water. Their prompt action in face of danger prevented serious damage to cables and avoided serious delay to Shirley Exchange transfer.

Middlesboro Section.

Men concerned.

A. Chapman, S.W.II.
J. F. Chapman.
J. E. Iles.

Action.

River Leven in flood. A. Chapman waded river waist deep to Stokesley Exchange and finding equipment in danger telephoned for assistance. J. F. Chapman and Iles came through the river, and the men together raised M.D.F. and switchboard and thus maintained the service from interruption.

Mr. William Cruickshank.

Mr. William Cruickshank, Assistant Staff Engineer, of the Research Section, Engineer-in-Chief's Office, who retired from the service on 31st October, 1931, on attaining the age limit, has been Managing Editor of this Journal for 18 years and is well known to many of its readers at home and abroad.

He was born at Keith, Banffshire, on 26th August, 1871, and after a short period as S.C. and T. at Keith, he was transferred to Aberdeen in 1889. At Aberdeen he was employed as special wire telegraphist for the Aberdeen Journal and thus at an early stage of his career became closely associated with journalism. He studied technical subjects at Gordon's College, Aberdeen, and won the City and Guilds of London Institute Silver Medal in Honours Telephony.

He was appointed to the Engineering Department in 1901 and after a short period of service in Manchester, where he succeeded Mr. T. E. Herbert as lecturer at Manchester Technical College, he was appointed Sub-Engineer at Holloway Factory. In 1905 he was transferred to the Engineer-in-Chief's Office and assisted Mr. S. A. Pollock in research

Mr. W. Cruickshank.

work on loading coils. He produced the Telegraph Diagram Book in 1906 and the Telephone Diagram Book in the following year. This work was carried out practically in his spare time.

He pursued his studies at the Northampton Institute and after going through the complete course of training in Electrical Engineering, he took first place in the Final Examination in both the D.C. and A.C. courses and third place in Electromagnetic Theory and Vector Calculus. He then joined the teaching staff of the Institute and for fourteen years lectured on Telephony and Telegraphy with outstanding success.

During the early war period he assisted Col. Purves in designing new signal apparatus for the Army in the field. In 1916 he was sent to Chatham and became Chief Signal Instructor to the Eastern Command. After the Armistice he was sent to Cologne and took charge of the installation of a 25-position Exchange for the Headquarters of the Army of the Rhine. For these services he received the personal thanks of the Secretary of State for War.

Mr. Cruickshank organised and installed the Post Office exhibit at the British Empire Exhibition at Wembley in 1924. The exhibit included the first Director, C.C.I., and Tandem models ever erected, manual exchanges, printing telegraphs and a model of the P.O. Tube Railway. For the opening ceremony he proposed and arranged successfully the sending of a message by the King round the world by the Imperial route. This was accomplished in 80 seconds.

He was appointed Executive Engineer in charge of the Telegraph Group of the Research Section in 1924 and in 1928 he succeeded Mr. P. J. Ridd as Assistant Staff Engineer in charge of the groups dealing with telephone transmission, telegraphs, cable research and cable acceptance. He has edited the Research Bulletin since its inception.

For several years Mr. Cruickshank was examiner in Telephony and Telegraphy for the Civil Service Commissioners for the Inspectors and Assistant Engineers' examination. He has written many articles and papers on various subjects and was awarded the I.P.O.E.E. Senior Bronze Medal for his paper on "Voice Frequency Telegraphs." He is Reporter on Telegraph and Telephone Progress for the Institution of Electrical Engineers. He was responsible for and installed the Electrical Communications Section of the recent Faraday Centenary Exhibition at the Albert Hall.

The foregoing is but a sketch outline of Mr. Cruickshank's fine record of zealous and useful service. A strong and honest man in every sense of the term, he throws himself wholeheartedly into every work he undertakes. The greater and more difficult the task, the more he enjoys its accomplishment. He possesses to a high degree some indefinable personal quality which turns colleagues and associates into fast friends, and which earns the love and respect of younger men and subordinates. In spite of the many years he has spent in the Metropolis he still carries about him the refreshing atmosphere of his native Scottish hills and throughout his career he has nobly upheld the best traditions of his countrymen.

Those of his colleagues who have been closely associated with him in the conduct of this Journal will greatly miss him. The consistently high standard and the eminently successful career which the Journal has enjoyed are due in bountiful measure to Mr. Cruickshank's painstaking and farseeing work on its behalf. Contributors and subscribers all over the world will regret his retirement from the Managing Editor's chair at the end of the present volume.

A fine cricketer, an expert swimmer and water polo player, a sound half-back but an indifferent golfer, Mr. Cruickshank has always enjoyed robust health and his fine physical fitness remains unimpaired. He is still a young man mentally and physically and it will be characteristic of him to make as great a success of his retirement as he has made of his official career.

Rather wistfully, we say to him as official colleague, as Managing Editor, but above all as friend —Farewell. We wish it had been possible to defer the occasion for the saying of it a little longer. But no man has better earned his freedom, and colleagues, friends, readers and contributors will all join in wishing him and Mrs. Cruickshank very many years of continued good health and happiness.

J.J.McK.

DISTRICT NOTES.

LONDON DISTRICT.

Growth of Telephone System.

Direct Exchange lines	420,808
Telephone Stations	708,154

Increase during Quarter : 2991 exchange lines and 4377 stations.

During the three months ended 30th September, 1931, the following changes occurred :—

Telephone Exchange.—Net increase of 300 miles overhead and net increase of 59,182 miles underground.

Telephone Trunks.—Net increase of 8,690 miles underground.

Telegraphs.—Net increase of 77 miles underground.

The total single wire mileage at the end of the period under review was :—

Telephone Exchange ...	2,985,158 miles.
Trunks	121,188 ,,
Telegraphs	26,771 ,,
Spares	56,845 ,,

Whitehall Automatic Exchange.—The new Whitehall Automatic Exchange was successfully opened on the 3rd October at 1.30 p.m., the following lines being transferred to the new equipment :—

1429 from the hypothetical exchange on Gerrard.
408 ,, Regent.
428 ,, Gerrard.
23 ,, Victoria.

A total of 1868 junctions and order wires was also transferred.

A short article on Whitehall Exchange is given elsewhere in this Journal.

" Eng " Repair Service on Automatic Exchange.—The Engineering Repair Service instituted on July 15th this year continues to function satisfactorily and is without doubt proving effective in clearing subscribers' troubles expeditiously and quickly bringing to notice common apparatus faults. The fact that subscribers by dialling " ENG " can obtain direct access to the Test Desk, where an immediate test of the line and apparatus can be carried out to ascertain the nature of the conditions causing trouble, is of considerable value in effecting improvement in the service given to each individual subscriber.

Conversion of Manual-Automatic Exchange Traffic to Voice Frequency Working.

Manual Exchanges.—The conversion of the " A " position cord circuits to Voice Frequency working at 64 manual exchanges throughout the District is proceeding rapidly. The exchanges are divided into groups to be converted in priority order and it is hoped to have the first group of five exchanges ready for change-over in January.

Automatic Exchanges.—Spare Keysender " B " apparatus at the working automatic exchanges has been collected by the equipment contractors for conversion to straightforward Junction working and it is anticipated that the first group of 45 junctions will be available early in January. The tuned V.F. Relay sets are being fitted by the Department's staff. As groups of junctions are converted to V.F. working, further quantities of K.S.B. apparatus will be made available for modification to a straightforward junction basis.

Introduction of Trunk Demand Working to Birmingham.

To cater for the first step in the introduction of the " Demand " scheme on the Inland Trunk System, the record positions on the 5th Floor, G.P.O. South, have been provided with additional outgoing multiple and also relay sets for extra record circuits from the London Automatic Exchanges. The Department's engineers have installed a 22 volt S.F.J. Transfer position in the Trunk Exchange 3rd Floor. Circuits from the 5th floor multiple worked on S.F.J. principles to this position are utilised to reverse calls from manual subscribers over the junction route from Trunks to the manual exchange Trunk position, thus ensuring that the Demand operator's answering supervisory lamp is controlled by the subscriber's switch-hook.

Demand working to exchanges in the Birmingham local fee area was inaugurated on Saturday, November 28th. In the meantime a large suite of Demand and Delay positions is being installed under contract on the 4th floor, G.P.O. South. This suite is wired for 50 volt working and it is hoped to transfer all Demand and Record work thereto in April, 1932, thus releasing the 5th floor positions for modification to 50 volt working. It is expected that these positions, after conversion, will be used solely for calls from automatic subscribers in the London Director area.

Toll Control.

Automatic Exchanges.—Rearrangements of the " A " board distribution at Director exchanges in the five mile circle are being carried out by the Department to clear positions ready for the contractors to instal the necessary Relays Sets, Time Checks and Cord circuits for controlling Toll calls from the local exchange, thus giving considerable relief to the Toll " A " exchange.

Manual Exchanges.—Similar rearrangements are in hand at Manual Exchanges in the five mile circle. In these cases the cord circuits, time checks and associated apparatus will be installed by the Department's local staffs. Two entirely new features introduced on these positions are the Time Check circuits which give a visual indication of the actual conversation time on Demand Calls, and the Visual Idle Indicating lamps which indicate only one idle circuit at any instant. Directly this idle circuit is appropriated the next idle circuit lamp is illuminated.

Ford's Works at Dagenham.

As is generally well known, Messrs. Ford are opening a very big factory at Dagenham, Essex. The site is 1¼ miles square. One side skirts the Thames; the opposite side of the main road from London to Tilbury. A lead-in of 1¼ miles is not often met with, but in this case the offices are at the riverside. Many exchange lines and private wires were required and literally hundreds of extensions. One of the buildings is approximately 1000 feet square; the floor space is kept clear of everything except things essential for motor-car building.

Machinery and furniture were removed from the Manchester Works and brought by special trains to Dagenham. On arrival they were assembled and got ready for work in short time. Telephones were required for use as the furniture was placed in position.

At the outset it was arranged that the external staff should take all the telephone work except the fitting of the switchboard, this being an " Installation " area. Cables and wires were run about the building in all manner of places to avoid fouling the machinery to be used. Telephones were placed at selected spots, connected up and left so that when the furniture was placed in position the telephone was lifted on to the table and service was available at once.

The success of the work by the Post Office brought from the chief representative of Fords in this country the statement that he was well pleased with what had been done and turning to his colleagues remarked :

" *Who says that a State service cannot be efficient?* "

Messrs. Baldry, Chief Inspector, and Hawkes, Inspector, were responsible for the work.

Teleprinter Working.

The number of circuits in the C.T.O. modified to Teleprinter working is increasing apace, and there are now 290 working positions so equipped.

Two recent events of widespread interest, the General Election in October and the feverish activity in Dublin in November have necessitated provision of special telegraph facilities. It is pleasing to note that the plant installed for these occasions met the demands upon it without difficulty or hitch.

A S.T. & C. 12-channel Voice Frequency Telegraph equipment has been installed in the C.T.O. The equipment is of a new pattern and has been provided to facilitate the release of physical circuits on the long underground cables to the north. The Voice Frequency equipment has been provided by the S.T. & C. Ltd., and the accompanying batteries, generator, etc., were provided by the Engineers of the London District. The system provides for the C.C.I. new standard frequency spacing of 120 cycles. The present equipment has a capacity for 18 channels, and it is possible to extend the racks to cover a total equipment of ten sets of 18 channels each. A description of the special features of this new equipment will no doubt appear in a later issue of the Journal.

SOUTH MIDLAND DISTRICT.

Diversion of P.O. Plant.

Guildford.

The main London-Portsmouth Road passes through the towns of Guildford and Godalming and during the summer months the traffic carried by this road is exceptionally heavy. Very bad congestion occurs at week-ends and it is a common occurrence for a line of vehicles a mile in length to be held up owing to congestion in Guildford High Street. Somewhat similar conditions, but less serious, occur at Godalming.

With a view to diverting the bulk of the traffic from the narrow Guildford and Godalming streets the Surrey County Council are constructing a by-pass road, which commences at a point approximately one mile N.E. of Guildford and rejoins the present Portsmouth Road at Milford. The latter place is approximately two miles S.W. of Godalming, so that when the new road is completed both Guildford and Godalming will be by-passed.

The new by-pass road crosses the Hog's Back near the old Toll Gate at Compton Lane and, owing to the steepness of the hill, a cutting approximately 120 feet wide and 40 feet deep is being made, so that the old Guildford-Farnham Road will be carried on a bridge above the new road.

In order that the cutting and bridge work could be carried out as quickly as possible a temporary road was made on the adjoining fields, so that the whole of the Guildford-Farnham Road could be cut through and the bridge constructed without hindrance from traffic.

The following P.O. plant was affected by these operations :—

London-Southampton-Main overhead trunk route, 58 wires.
London-Southampton-Main trunk cable, 254/20 M.T.
Guildford-Reading-Basingstoke trunk cable, 74/70 Quad.
Guildford-Aldershot-Farnham trunk cable, 54/70 M.T.

The alterations necessary to the overhead route presented no difficulties, but the cables, which are all loaded and balanced, required special treatment, as approximately 120 feet of the two duct lines would have to be cut out.

In the case of the 74/70 and 54/70 cables it was decided to draw out one length of each (176 yards), and to make good the circuits by providing four 15 pr/20 aerial cables erected on four poles sufficiently high to avoid fouling the crane used for the bridge works.

The remaining cable, 254/20 M.T., carries a large number of important telegraph, and side and phantom telephone circuits, the latter being repeatered at Guildford, and in view of the expensive and tedious work involved in providing a special cable, tapping out, numbering, diverting, etc., and also the fact that 27 special circuits for the Schneider Trophy arrangements were working through the

cable, it was decided to try and keep the cable intact whilst the road and bridge works were in progress.

To support across the cutting the 120 feet length of cable, the weight of which is approximately ½-ton, it was necessary to provide two short stout poles, with back stays, and to erect between them three 7 strand suspension wires, and to sling the cable in a similar way to an aerial cable.

In view of the weight of the cable and the fact that it was fixed at either side of the cutting, it was necessary to ensure that there should be no sag in the suspension wire. This was effected by erecting the top two suspension wires six feet above the ground and lashing them to the lower suspension wire which was at ground level and carried the cable. Then by adjusting the lengths of the slings the cable was carried across at the same level as the duct line.

The cable was wrapped to prevent possible damage, but in order to facilitate the road works the Surrey County Council decided on blasting operations, and as this work was carried out underneath and close to the cable special protection had to be provided. A tight wrapping around the cable would not have prevented the cable from being hit and damaged, and it was therefore decided to provide a cage approximately two feet in diameter made up of expanded metal and slung from the suspension wire so that the cable was totally enclosed.

The cable will probably remain suspended in this manner for approximately six months, and the arrangement for protection and suspension has so far proved quite satisfactory.

Although the cable will to a certain extent hinder the bridge works, the Surrey County Council Engineer, on learning of the importance of the circuits concerned, readily agreed to the proposal and has given every assistance possible, particularly in regard to preventing possible damage to the cable.

Apart from the inconvenience which would have been caused by having a large number of important circuits diverted into temporary cables for a long period, the retention of the cable in its original position has resulted in a large saving in labour costs.

NORTH EASTERN DISTRICT.

Laying of Three 4″ Steel Pipes Across River Ouse at Boothferry.

Owing to the failure of the armoured trunk cables across the River Ouse at Boothferry and the evident insecurity arising from the use of this type of cable, it was decided to lay three 4″ steel pipes at a point some little distance to the west of the existing crossing and to draw in lead-covered cable of the ordinary type.

The laying of these pipes proved to be a much more difficult job than was anticipated, as the contractor's original proposal to pull the pipes across the river bed by means of a traction engine and steel hawser attached to the pipes by a torpedo head failed after several trials, and ultimately that method had to be abandoned.

The procedure successfully adopted was that of

Fig. 1.—General view showing commencement of Runway.

providing a rail runway in the fields adjoining the river bank, on which the whole length of the three pipes, screwed and welded, necessary for the crossing, was laid.

This runway led to the river bank and then sloped down to the river bed.

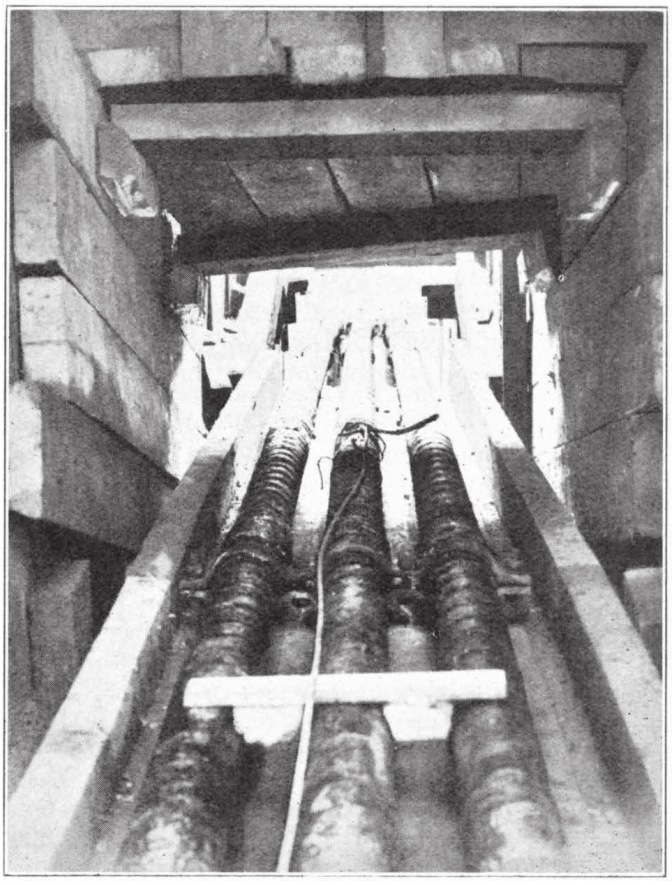


Fig. 2.—Pipes down Chute to water.

Before the pipes left the runway, steel hawsers were attached to the pipes at different points in the length, and, as the pipes entered the river, the other ends of the hawsers were fastened to barges.

After the first barge had proceeded a distance across the river, along the route already dredged, the second barge took up its position to " hold up " the second length of pipe, and so on, until six barges were

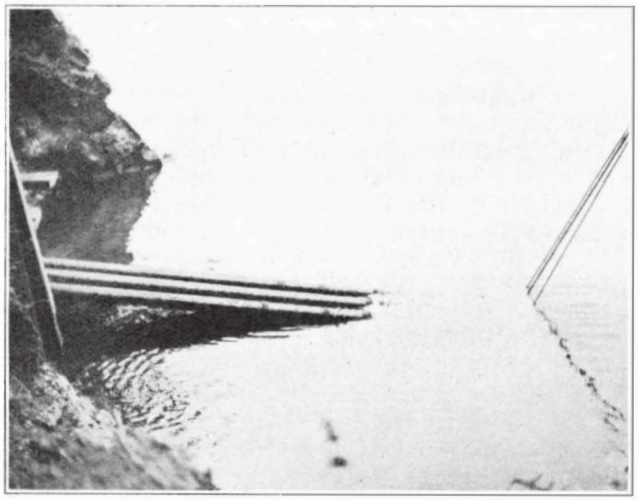


FIG. 3.—PIPES BEING DRAWN DOWN CHUTE INTO WATER WITH SUSPENSION HAWSER FROM FIRST BOAT.

strung across the river, each holding up a length of pipe.

At a given signal, the barges simultaneously lowered their lengths into the trench, and the crossing was complete.

FIG. 4.—THE BARGES IN POSITION.

The tests proved that the whole length of pipes was satisfactorily laid and the cable was then drawn in, tested, and found to be in order.

ERECTION OF POLES BY CRANE FITTED ON 3-TON ALBION LORRY.

The forward movement as regards costs could only lead in the direction of the greater utilization of machine-power instead of man-power, and one of the greatest strides in that movement was taken when it was decided to endeavour to cut man-power out of the work of handling poles during erection and recovery.

Between Chalk Hill and Grimsby recently it was

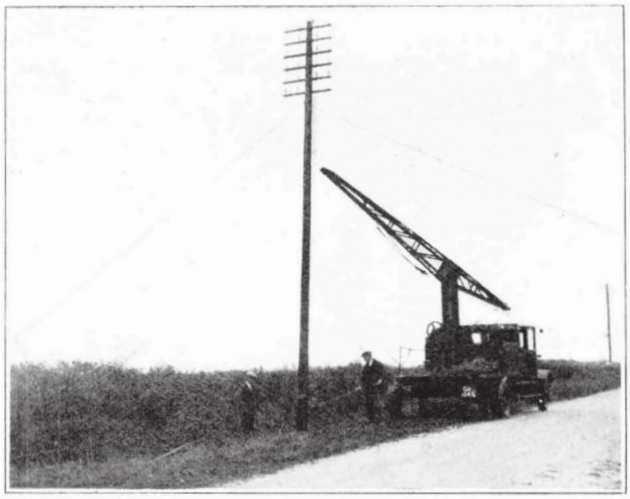


FIG. 1.—CRANE ON 3-TON ALBION LORRY. LIFTING JACK IN POSITION.

necessary to effect pole renewals, and the work was suitable for the trial of the 3-ton Albion lorry fitted with jib crane.

The poles to be renewed were first lifted clear of the ground level by means of pole jacks and pushed by a jack to the side of the hole to make room for the erection of the new pole.

FIG. 2.—ENLARGING HOLES WITH AUGUR.

As the diameter of the new pole was larger than that of the recovered pole, the pole hole was enlarged by using a 14″ Iwan Augur. After this enlargement, the lorry was jacked up, and the new pole was lifted by the crane and jockeyed into position immediately over the pole hole, lowered into the hole and the ground punned and finished off. The wires were changed over, and the recovered pole lowered to the ground.

The work in question also provided for the erection of A poles at some points in place of the existing single poles.

The same procedure was followed as regards the

lifting of the existing pole out of the ground, but the pole hole now vacated would not, of course, take the A pole, and it was necessary, therefore, to enlarge that hole to approximately *half the size* of the pole hole ordinarily required for an A pole, owing to the fact that the crane could lift the A pole vertically in such a way as to drop it into position : the hole was then filled and punned, wires changed over, and the recovered pole dropped in the manner already illustrated by the photographs.

It is of interest to know that the maximum working load of the crane is 1 ton and the maximum operating radius measured from the central pillar, and when lifting over the side of the lorry, is 9′ 6″. The height of the lift is approximately 20′, thus allowing poles up to 40′ being dealt with.

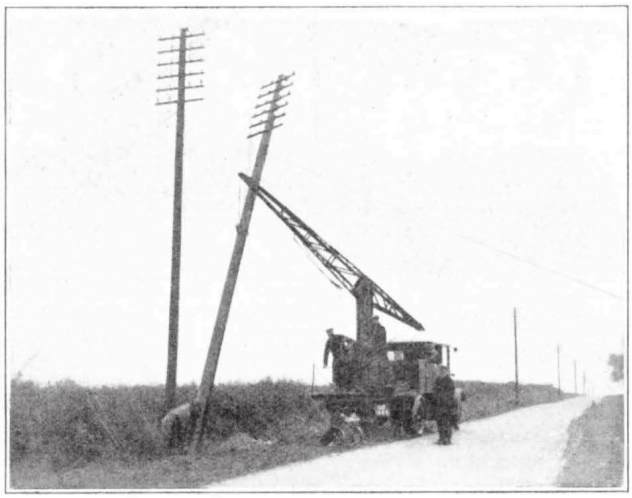


FIG. 3.—NEW POLE BEING LOWERED INTO POSITION.

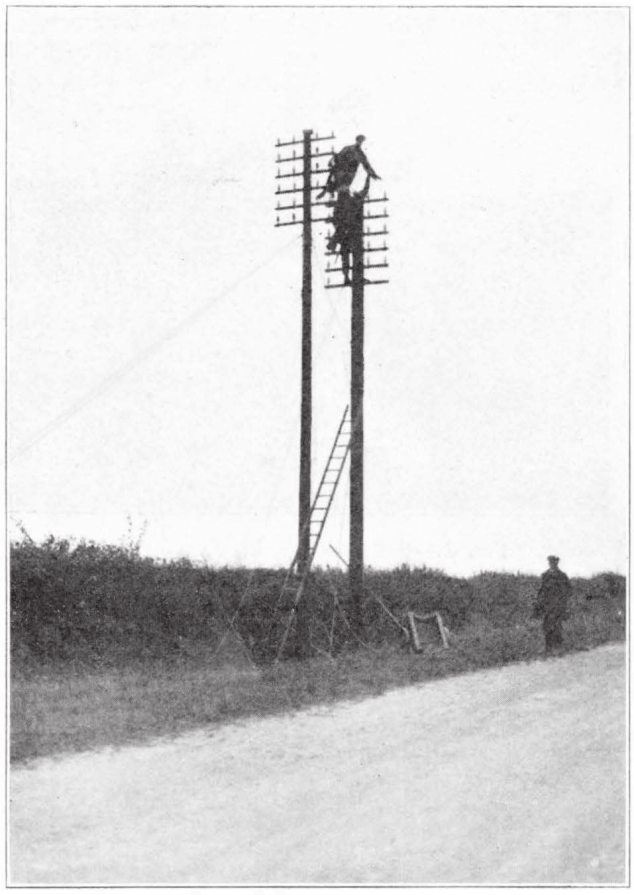


FIG. 4.—CHANGING OVER THE WIRES.

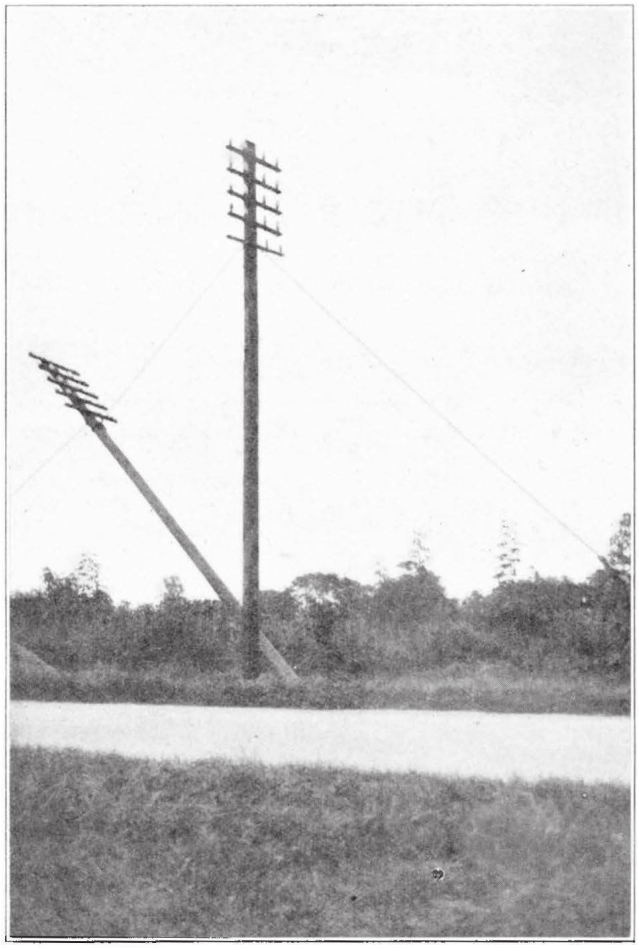


FIG. 5.—LOWERING RECOVERED POLE.

This is only a brief statement of the use of the crane lorry, which cuts out all risks of accident to the men in the handling of poles of the sizes referred to, and consequently the " safety first " policy is being considerably furthered by the utilization of the crane lorry method of erecting and recovering poles.

It does not require much imagination to appreciate the possibilities which lie before us in this forward movement, as the saving of man-labour has not only a direct financial effect upon costs, but an indirect beneficial effect upon the men, which in turn must prove to be to the financial advantage of the Department, inasmuch as it is reasonable to assume that the less power you take out of man, the longer he will last as an effective unit in our organisation.

NORTH WESTERN DISTRICT.

Visit to the North Regional Station (B.B.C.).

On a fine day in September members struck a new note and visited Moorside Edge. The approach, which was made from the Lancashire side, gave one that top of the world feeling which is experienced on the moors. On arrival, guides were provided, who first of all pointed out the items of interest outside the station, including the 500 feet masts. These are massive structures and are built up in seven sections The stay connections present a neat and efficient appearance. The wires on smaller poles carry the modulated current from the output valves to the Transformer Hut where it is passed to the aerial.

The station building is a one storeyed affair and appears strong enough to withstand the most severe weather. Ample accommodation is provided and everything looked spick and span. The lay-out in the various rooms was admired, particularly in the transmitting hall where are housed the transmitters for both the National and Regional aerials. The valves, which are in cascade of seven, had a low tension current of the astounding value of 1100 amps. Our guide mentioned the water cooling device and we spotted a temperature of 84°C. Broadcasting was taking place on one of the aerials and members saw the station under working conditions. The transmitting hall was strangely quiet except for the faint strains of music from the " listening " room.

In the engine room are four Diesels, each of 345 h.p., three of which are used when both transmitters are in action. In the event of a breakdown of the prime movers, a 220v/2000 A.H. battery is available to maintain the station for 1½ hours. We were impressed by the " batteries " of motor-generators which supply the H.T. Each set consists of a motor directly-coupled to two generators, each of the latter having two windings and two sets of commutator segments. Each winding generates 300 volts and, the four sets of windings being in series, a total voltage of 1200 is supplied without the special need of a highly insulated machine. (This arrangement was introduced, it is believed, for the first time by the Department at Rugby). The maximum voltage to frame is only 300. One set is for the North Regional, one for the North National and one is a standby.

The many safety devices for the protection of the staff and the apparatus were interesting. Our imagination was again aroused by the label " Ice melting plant." This apparatus allows the aerial wires to be earthed at one end and a low tension current passed along just sufficient to warm the wires of the aerials.

The station is started up half an hour before transmission commences and members had the opportunity of seeing the preliminary preparations for tuning up the second transmitter. These included visits by the engineers on duty to various rooms for the purpose of throwing in numerous switches and checking meters according to a routine plan based on " Safety first."

The party also saw the microphone and the gramophone which will be used to provide a programme in the event of the complete failure of the land lines connecting the studios with the station.

The visit was unique, full of interest and was consumated by an excellent tea at the " Flying Horse," Rochdale.

Retirement of Mr. S. Upton, M.I.E.E.

Mr. S. Upton.

Stephen Upton, Assistant Superintending Engineer, North Western District, who retired on the 31st August, 1931, began his service as a telegraphist at Grimsby in 1887. In 1896 he was transferred to the Engineering Department as a Junior Clerk, and by 1900 had attained Engineer rank, finally becoming Assistant Superintending Engineer in 1928. During these years he acquired wide experience in telegraph and telephone practice in London and the Provinces as well as in Ireland.

His entry into the Engineering Department coincided with the acquisition of the Trunk Service in 1896, and from 1902 to 1909 he was engaged in telephoning London in competition with the old N.T. Company. He was soon grappling with automatics and carried out two of the earliest transfers to Auto. working—Accrington in 1914 and Blackburn in 1916.

Stephen Upton had always a very keen interest in educational work, and while still a telegraphist did pioneer work in connection with technical classes and examinations. Throughout the many years he was in charge of Engineering Sections he maintained a lively personal interest in the recruitment and training of his staff, regarding this as not the least

important of a Sectional Engineer's managerial responsibilities.

In I.P.O.E.E. matters his enthusiasm was unbounded. In addition to having been a member of the Council he contributed many papers and could always be counted upon to attend the meetings of the local Institution and, what is more, to take a valiant part in the discussions.

He was as excellent on paper as in the realm of practical engineering. Himself rapid, bright, trenchant and concise in style, and a scrupulous grammarian, he was impatient of anything less than the best in official correspondence; and an I.P.O.E.E. afternoon that will long be remembered was when he read a paper entitled " Official correspondence and Report Writing."

He respected traditions; particularly the ancient tradition that " Manners maketh the man." Very approachable, sympathetic, genial and courteous, unsparing of self, he possessed in a unique degree the faculty of laying himself alongside all sorts and conditions of men. The little leisure he could snatch from a very full official life he devoted to practical sociology and kindred aims, to which he now looks forward to giving all his energies.

SOUTH WALES DISTRICT.

Retirement of Mr. G. S. France.

A long career in the Service was brought to a close by the retirement of Mr. G. S. France, Sectional Engineer in charge of the Cardiff Section, at the end of September. Entering the Service at Liverpool in 1887, Mr. France was transferred to the Engineering Department in 1891 and after various moves was stationed in Birmingham, where he reached the rank of Assistant Engineer in 1911. In 1915 he was promoted Executive Engineer and was given charge of the Cork Section. He remained in Ireland until the formation of the Irish Free State, when he was transferred to Cardiff. In addition to his capabilities as an engineer and administrator, Mr. France possessed a happy and genial disposition and was universally esteemed by everyone who knew him.

Expression was given to the high regard held of Mr. France at a well-attended smoking concert on the 31st October, when he was presented with gifts of silver plate by Mr. T. Devereux, senior Assistant Engineer in the Cardiff Section, in the unavoidable absence of Mr. Terras, Superintending Engineer. Representatives of all engineering grades testified to the happy relations which had always existed between Mr. France and the whole of the Staff, and to the regret at his retirement. Particularly gratifying was the presence at this function of the Head Postmaster of Cardiff and the District Manager, both of whom paid a glowing tribute to the generous co-operation they had invariably received at the hands of Mr. France. It is pleasing to record that he retires in the full vigour of bodily health.

SOUTH WESTERN DISTRICT.

Retirement of Major W. M. Batchelor.

A large and representative gathering assembled at a smoking concert at St. Stephen's Restaurant, Bristol, on 26th October, to take official leave of Major W. M. Batchelor, D.S.O., M.C., Superintending Engineer. The Chairman of the evening was Mr. A. Gray, Assistant Superintending Engineer, and the guests included Mr. Blandford Harris, Postmaster-Surveyor of Bristol, Mr. E. F. Simmons, of H.M. Office of Works, and Mr. A. Bristow, District Manager.

Major Batchelor, who is a well-known figure in Bristol social circles, had a distinguished career in the Post Office. He joined the Central Telegraph Service in 1885, was transferred to the Engineering Department in 1892, and was Assistant Superintending Engineer in the N.E. and E. Districts before being promoted to Bristol in 1927. He rendered conspicuous service with the R.E. Signals during the war and was awarded the Distinguished Service Order and the Military Cross.

After the evening had been opened with musical items, the presentation of a fitted " Compactum " wardrobe was made by the Chairman on behalf of the Staff of the South Western District. In a felicitous speech, the Chairman referred to the admirable work carried out by Major Batchelor during his Official career, and echoed the general feeling of the Staff in wishing him a long and happy retirement.

Supporting speeches were made by Mr. Blandford Harris, Mr. R. C. Balcombe, Sectional Engineer, Taunton, and Mr. D. Williams, Staff Officer, and included references to Major Batchelor's courteous and sympathetic treatment of his Staff, and to the athletic prowess which enabled him to remain a member of the Tennis Club First Team to the exclusion of many younger aspirants!

Major Batchelor in reply expressed his appreciation not only of the personal gift, but more especially of the sentiments which had been expressed. He said that his work in the South Western District had been facilitated by the harmonious way in which the Staff worked together, and by the cordial relations which existed between the Department and all outside bodies. He paid a special tribute to the loyal assistance given him by the Assistant Superintending Engineers, Messrs. A. Gray and J. Baxter.

An excellent and varied musical programme, provided by local amateur and professional talent, was concluded by the singing of " Auld Lang Syne."

Bristol Automatic Area.

Automatic working in the Bristol Area was inaugurated at midnight on 28th November, 1931, by a successful simultaneous transfer from five existing manual switchboards to ten new automatic exchanges.

The old exchanges closed down were Stoke Bishop, Westbury-on-Trym, Kingswood, Whit-

church, and, last but not least, the old Central Exchange, reputed to be the first Central Battery Exchange in Europe.

Some idea of the extent of the operations will be gathered from the following schedule of the ten new exchanges now working :—

Exchange.	Initial Equipment Uniselectors.	Ultimate Capacity.
Central	5310	9600
West	3515	5400
North	2160	4300
Easton	1620	3000
Westbury	1260	2700
South	1170	2600
Bedminster	990	2000
Kingswood	630	1400
Stoke Bishop	630	1200
Whitchurch	95	300

Six further exchanges, namely, Pill, Filton, Frenchay, Fishponds, Keynsham, and Long Ashton, will be converted to automatic working in due course.

The transfer of the trunk exchange from the Head Post Office to the new exchange at Telephone Avenue was effected on October 10th, and the operations on the 28th November were divided into two main stages, *i.e.*, :—

(*a*) An advance transfer of junctions and short trunks at 7 p.m.

(*b*) The main transfer of subscribers together with the remainder of the junctions at midnight.

The system is not " director," but standard 5-digit Strowger employing discriminating selector repeaters, and the Bristol Area is unique in that it is the first in Great Britain in which the entire Strowger equipment is mounted on pressed steel channel shelves on single-sided racks.

The fine new building at Telephone Avenue will accommodate not only the Central Automatic Equipment and the combined trunk and auto-manual switchroom, but also the repeater station, which is not yet completed. The manufacture and installation of the exchange equipment was carried out by the Automatic Telephone Manufacturing Co. of Liverpool, and the repeater apparatus is being provided by the General Electric Company.

It is hoped that it will be possible to publish a descriptive article on the Bristol automatic equipment in the next issue of the Journal.

Main Cabling by Direct Labour.

The Engineer-in-Chief has decided that the Bristol-Yeovil-Dorchester cabling and loading shall be carried out by direct labour, and a special organisation is being set up to ensure that the work is completed with a maximum of expedition and economy. These will be the first cables to be laid in this District under the Trunk Reorganisation Scheme, and will consist of 20 lb. conductors in quad formation. The cable at the Bristol end will contain 160 pairs, tapering to 74 pairs at Dorchester. Provided that the specified unbalance limits will not thereby be exceeded, it is intended that all joints shall be made on a systematic basis, with the exception of a single test selected joint in the centre of each loading coil section.

Faraday Centenary.

In connection with the Exeter Faraday Centenary Celebrations, an Exhibition has been arranged to take place at the new Science Laboratory, Exeter University College, on December 10th-12th, 1931. A Post Office Engineering exhibit is to be provided which will include many features similar to those of the P.O. display at the Faraday Exhibition in the Albert Hall, London, in October last. It is hoped to give a full account in the next issue of the Journal.

D.A.B.

SCOTLAND EAST DISTRICT.

A Robust Main Cable.

We of the Scotland East Engineering District had an experience recently which may be worth while relating outside local channels. So much care and attention is given to balanced and loaded cables that we are inclined to look upon them as being particularly vulnerable, and it was surprising when we discovered one robust specimen which successfully withstood the ravages of nature .

The cable between Edinburgh and Newcastle is a composite one of 170 pairs, and in addition to carrying long distance trunks and telegraphs it is an essential link in the Trans-Atlantic telephone service. This cable is in the main road south from Edinburgh to Newcastle *via* Galashiels, and at a point 13 miles S.E. of Edinburgh the sandy sub-soil was washed away as a result of serious flooding, which occurred during the afternoon of the 17th August, and the road subsided at two places. One of the breaks extended from one side of the road to the other and varied in depth from 10 to 25 feet. The other break was more localised, but at each the cable and 2-way duct were found exposed and unsupported for approximately 12 yards.

A breakdown gang was despatched to the scene of the washout and emergency measures were taken to avoid a serious breakdown. The ducts were broken off and the cable was suspended from poles lashed together and placed across the gaps. When the filling-in operations were completed, split 2-way ducts seated on a bed of reinforced concrete and protected on top by concrete were installed to restore the duct line. The cable was not damaged, but it had acquired about 18″ of slack which could not be easily handled and it was cut out at the nearest joint without interrupting any of the many working circuits.

The accompanying photographs taken on the 18th August show the breaks in the roadway and the position of the P.O. duct and cable in relation thereto.

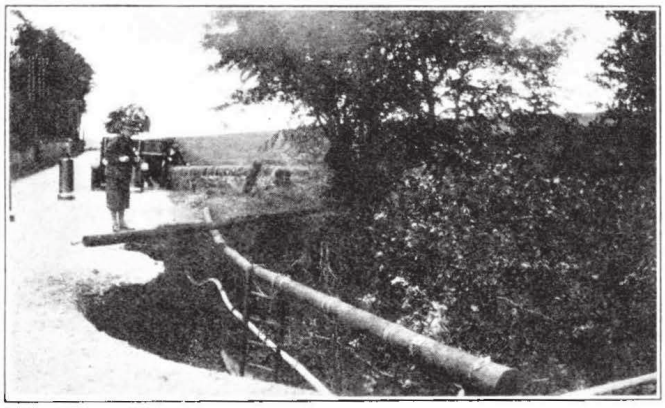


FIG. 1.—SUBSIDENCE NO. 1. VIEW FROM EAST.

The gaps were filled in with stones and the road was re-opened for traffic late in the afternoon of the 18th.

As a matter of interest it should perhaps be explained that the heavy rain was not alone responsible for the flooding. The Moorfoot Hills, which rise to a height of over 2,000 feet, are on one

FIG. 2.—SUBSIDENCE NO. 2. VIEW FROM SOUTH EAST.

side and at some distance from the road there is a valley of considerable extent in the high land. As the soil in this valley is of a peaty nature there is a natural reservoir draining a large area which fills up and periodically every two or three years bursts and empties itself. Assisted by the abnormal rainfall, this is what happened on the 17th August when the

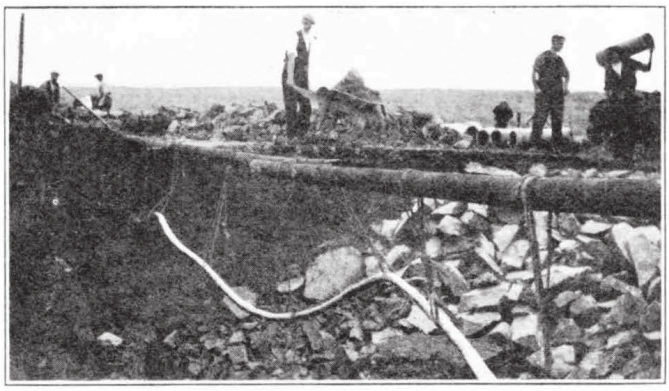


FIG. 3.—SUBSIDENCE NO. 2. VIEW FROM NORTH WEST.

roads from the hills were transformed into rivers. No system of drainage could cope with such conditions. It was, as a matter of fact, the presence of a stone culvert which indirectly caused most of the damage. This drain crossed the road and the rush of water through it started the shifting of the sub-

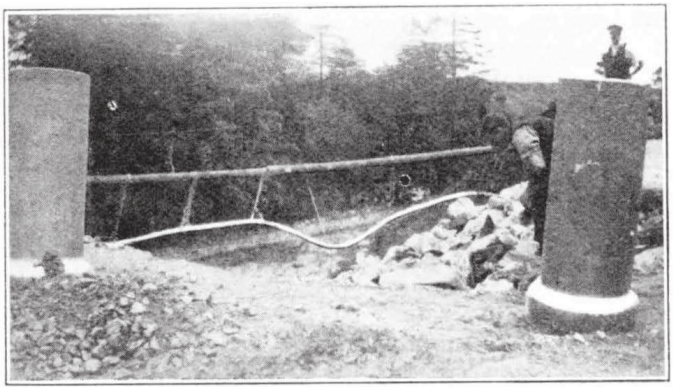


FIG. 4.—SUBSIDENCE NO 2. VIEW FROM SOUTH WEST, SHOWING EH—JH—NT CABLE SLUNG ON POLES.

soil, the drain broke away piece by piece and the undermining process continued until eventually the entire surface of the road collapsed.

ROBT. R. RAE.

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS.

NORTHERN CENTRE.

A paper on " District Accounting " was read on the 18th November, 1931, by Mr. T. Fewster. The author laid stress on the need for a clear understanding of the accounting requirements by all grades, in order that their work should be valuable and fruitful. He outlined the responsibilities of the Superintending Engineer in regard to bulk and detail control of funds, and traced the processes from the preparation of the Annual Estimates to the issue of Allotments, and thence through the systems of bulk and detail control of funds. The progress of Maintenance and Works expenditure under Labour and Stores was then traced from the Primary Voucher to the Cost Statement; and it was shown how the costing information was " thrown up " in the course of the financial accounting. The various steps from Estimate to Authorization of a Works Order, and the progress to " closing " of a Works Order were outlined. Some useful lantern slides accompanied the paper, which provoked an interesting discussion in which several members took part. The discussion was opened by Mr. P. D. Mathie, an A.G.D. auditor visiting the District, who said the paper was valuable in giving an idea of unity in the accounting system. He regarded the preparation of Primary Vouchers as the foundation stone of sound accounting, and appealed to all grades to use the information the accounting system provided and not to leave it to the " next man in the chain " to take the initiative.

Mr. Fewster's paper describes the District Accounting system in a simple, direct manner and the paper can be regarded as being particularly useful to all who wish to obtain a general knowledge of the Departmental system as practised in the Districts.

Annual Dinner.

The Northern District Annual Dinner will be held on Saturday, the 27th February, 1932.

SOUTH WESTERN CENTRE.

The first meeting of the Session was held at the Royal Empire Society Rooms, Bristol, on October 26th, 1931, when over 50 members attended to hear the annual address, delivered by Major W. M. Batchelor. The speaker touched on many aspects of Departmental work, with special reference to costs and to the recruitment and training of staff, and an interesting discussion followed.

The second meeting of the Session, presided over by Mr. P. T. Wood, was held on November 17th, 1931, when Mr. W. Ware read a paper entitled " A Commercial Wireless Coast Station." The paper dealt in a comprehensive manner with the purpose, design, equipment, and operation of the Portishead and Burnham Radio Stations, and was fully illustrated with lantern slides. The interest of the audience in the subject was evidenced by the keen discussion which followed, which indeed had to be curtailed owing to lack of time.

The theoretical information contained in Mr. Ware's paper was supplemented by practical contact with the plant described when on Saturday, 21st November, 1931, a party of 33 members visited Portishead Radio Station. Mr. Wilson, engineer-in-charge, and members of the staff explained and demonstrated the apparatus, and those able to be present enjoyed a most successful and informative afternoon.

D.A.B.

NORTH WALES CENTRE.

As far as can be gathered, the more intimately social atmosphere is not always conspicuous at formal meetings of the I.P.O.E.E., but the 1931-32 Session of the North Wales Centre opened auspiciously on 18th October with an item which, though not on the printed programme, was acclaimed with unanimous approval. Mr. J. G. K. Donaldson, recently promoted, relinquished his offices and terminated a long period of service to the Centre in particular and the Institution in general at the close of the last Session. The membership readily fell in with the Chairman's happy suggestion that suitable opportunity should be taken to mark the appreciation of the services rendered by the late Secretary. In the presence of the large gathering which attended the first meeting of the Session, Mr. R. A. Weaver asked Mr. Donaldson to accept a solid silver cigarette box and chromium plated lighter. The box bore a simple inscription : " J. G. K. Donaldson, I.P.O.E.E., 1925-1931," but the Chairman left no doubt as to the wealth of time and devotion that those years had evoked to guide the North Wales Centre to the highest aggregate membership on record in the Centre, and to a sustained interest of an enviably high order.

Characteristically, Mr. Donaldson, in reply, sought to devolve some of the speaker's encomiums and paid tribute to the generous assistance he had received from many of the members, especially from Mr. G. H. Carrier, who for a number of years past had voluntarily undertaken the responsibility of the lantern arrangements.

At the present time, when so many by-paths to the main road of experience are being opened up and vistas of the heights of new development revealed, the promise of a discussion on the Trunk Telephone Re-organisation Plan is perhaps the most intriguing that could be offered to the Telephone Engineer and the Traffic Executive. The offer was accepted by a large gathering to hear the Headquarter's Paper and included the District Managers from Chester (Mr. A. L. Barclay) and Birmingham (Mr. J. L.

Parry) together with representatives of their staffs, to whom the Chairman offered a hearty welcome.

To the author (Mr. J. S. Elston, A.M.I.E.E.) also the North Wales District is always prepared to accord a warm welcome as one born (actually) and bred (officially) within its borders, and the Chairman briefly recapitulated Mr. Elston's earlier connection with the District, recalling papers read 26 years ago (when the Institution itself was very young), and later, the titles bespeaking the versatility of a progressive career.

Although copies of the paper had been circulated, Mr. Elston left them to be assimilated at leisure and with an easy skill developed the intricacies of his projected diagrams to a logical and lucid conclusion in a lengthy, but never uninteresting, extemporary lecture that earned very hearty approbation.

Considerable interest was evinced in the explanation, which was given by Mr. W. H. Brent, of the constructional aspect of the new Aerial Cable system as revealed in the unfolding of an excellent series of films.

Time for discussion was unfortunately curtailed by the length of the major addresses, but sufficient was forthcoming to leave no doubt as to the fulfilment of the meeting's first anticipations, and an interest was aroused which can only be whetted by the adoption of the principles which had been expounded in the District which offers such favourable facilities for their further extension.

J.T.W.

THE INSTITUTION OF P.O. ELECTRICAL ENGINEERS.

Officers of Colonial and Foreign Telegraph Administrations who are engaged in Electrical Engineering Works may be admitted as Colonial and Foreign Corresponding Members respectively, after application.

Subscription payable annually in advance on 1st April in each year:

Colonial Members	...	...	£1 0 0
Foreign ,,	...	...	£1 10 0

These sums include Annual Subscription to the Journal of P.O. Electrical Engineers and the supply of all Professional Papers issued during the period covered by subscription.

Forms of application for Colonial and Foreign Membership can be obtained on application to

The Secretary,
Institution of P.O.E. Engineers,
G.P.O. (Alder House), E.C.1,

or the undermentioned gentlemen who have kindly agreed to act as representatives of the Institution in their respective countries:—

R. Badenach, Esq., B.Sc. (Melb.),
Chief Engineer's Office,
Postmaster-General's Department,
Treasury Gardens,
Melbourne, C.2,
Australia.

H. C. Brent, Esq.,
District Telegraph Engineer's Office,
Wellington, N.Z.

N. N. Banerjee, Esq., A.M.I.E.E. (Ind.),
Divisional Engineer, Telegraphs,
Calcutta West Division,
8, Wellesley Place,
Calcutta,
India.

A. T. Kingston, Esq., M.B.E., A.M.I.E.E.,
Office of the Chief Engineer,
Telegraphs & Telephones,
C.T.O.,
Colombo,
Ceylon.

A. G. Kellaway, Esq.,
P.O. Box 1077,
Johannesburg,
South Africa.

E. L. Jephcott, Esq., A.M.I.R.E.,
Chief Engineer's Department,
G.P.O. Box 391,
Salisbury,
South Rhodesia.

BOOK REVIEWS.

"Principles of Electricity." By Leigh Page, Ph.D. and Norman Ilsley Adams, Jr., Ph.D. Chapman and Hall, Limited. Pp. 620. Price 21/-.

This book is designed to provide students with a comprehensive training in the subject of electricity. It assumes a general knowledge of physics and the calculus. The first twelve chapters are devoted to electro-magnetism. The theory of alternating currents is discussed in Chapter XIII., whilst Chapter XIV. is devoted to A.C. and D.C. measurements. The next chapter is devoted to coupled circuits, filters and the transmission of alternating current over lines. Chapter XVI. discusses the properties of electro-magnetic waves whilst the final chapter is devoted to the peculiarities attending alternating currents of high frequency.

As a text-book dealing with the theoretical considerations encountered in practically every one of the many branches of electrical engineering, the book has everything to recommend it.

"Essentials of Electricity: Direct Currents." By W. H. Timbie. Chapman and Hall, Limited. Pp. 306. Price 12/-.

This useful little book sets forth in simple language the elementary theory of electricity and various aspects of its application in direct current electrical engineering. Each chapter concludes with a summary of the contents and is followed by a number of problems on the subject of the chapter.

"Electricity and Magnetism." By S. G. Starling, B.Sc., A.R.C. Sc., F.Inst.P. Longmans, Green and Co., Ltd. Pp. 345. Price 6/-.

This book is intended for students for Intermediate or Higher School Examinations. A small knowledge of the calculus is desirable, but alternative methods are given so that a student may be able to follow the work without it. The book covers the syllabus of the City and Guilds Examination and it can be recommended to students of the subject.

W.S.P.

OUTLINE NOTES ON TELEPHONE TRANSMISSION THEORY.

W. T. PALMER, B.Sc., Wh.Ex., A.M.I.E.E.

[*This Series will be published in book form in July next.*]

SECTION 10—*continued.*

(3) Cross-Talk Mesurement—Near and Distant End—Correction Factors.

Cross-talk between two circuits can be expressed by giving the ratio of the induced power (or voltage, if the circuits are of equal impedances) to the inducing power (or voltage). Thus in Fig. **36**, if an alternating voltage of 10 volts impressed on AB induces at CD (by virtue of unbalance capacity couplings, etc.) a voltage of 0.01 volt, then the cross-talk between AB and CD is $\frac{0.01}{10} \times 10^6$ millionths = 1000 millionths, or *1000 units of cross-talk,* where one unit of cross-talk is a ratio of one—millionth. This is known as *near-end* cross-talk. The ratio of the voltage appearing at C′D′, due to the voltage at AB and compared with it, is known as *distant-end* cross-talk and is also expressed in " millionths."

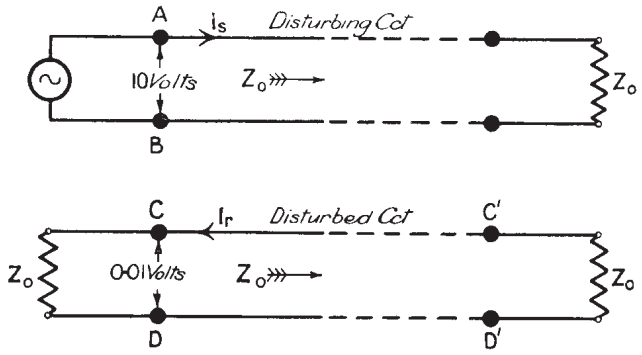


FIG. **36.**

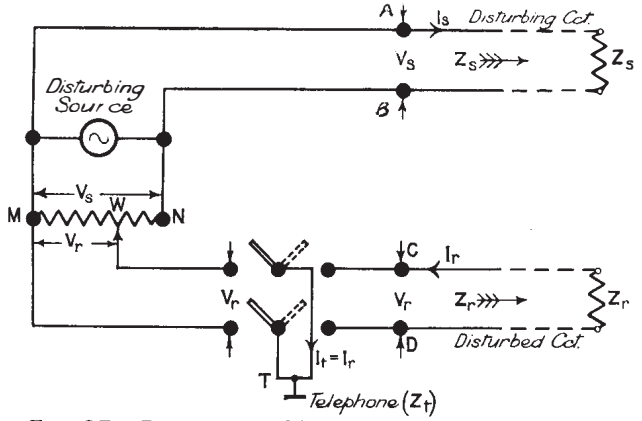


FIG. **37.**—PRINCIPLE OF MEASUREMENT ON CROSS-TALK BY COMPARISON.

Cross-talk can also be expressed as an attenuation, in decibels or nepers, since it is a ratio of current, voltage or power. This is perhaps a preferable method when repeatered cables are concerned, since most of the other transmission factors (repeater gains, terminal losses, etc.) of the system will be expressed in decibels or nepers. Thus, in the foregoing example where the cross-talk is 1000 millionths, if P_s be the applied power at AB and P_r the power induced in CD, then for equal impedances, Z_0, of the two circuits :—

$$10 \log_{10} \frac{P_s}{P_r} = 10 \log_{10} \frac{I_s^2 Z_0}{I_r^2 Z_0} = 20 \log_{10} \frac{I_s}{I_r} = 20 \log_{10} \frac{V_s}{V_r}$$

represents the near end *cross-talk in decibels.*

i.e., $20 \log_{10} \frac{V_s}{V_r} = 20 \log \frac{10}{.01}$

$$= 20 \log_{10} \frac{10^6}{1000}$$

$$= 60 \text{ dbs.}$$

$$\left\{ \text{or } 20 \log_{10} \left(\frac{10^6}{\text{Number of cross-talk units}} \right) \right\}$$

A *cross-talk attenuation of 80 dbs* corresponds to 100 " units " of cross-talk, and so on. (See Section 10 pp. (1)).

Measurement of Cross-Talk.—This can be carried out by means of a potentiometer arrangement such as that shown in Fig. **37**. V_s is a constant p.d. of mixed frequency (to represent speech conditions approximately) and the resistance MN is placed across the source V_s in parallel with the circuit AB. A known fraction of this voltage is tapped off by MW and a telephone T is placed across MW by the switch S. This switch places T alternately across MW and the circuit CD, in which a p.d., V_r, is being induced by V_s, the voltage across AB; when the noise heard in the telephone is judged to be the same in either position of the switch then :—

$$V_r = \frac{MW}{MN} \times V_s$$

i.e., the near-end cross-talk is $\left(\frac{MW}{MN} \times 10^6\right)$ millionths.

The Western Electric Cross-Talk Meter is based on this principle and is shown diagrammatically in Fig. **38**. The connections show those required for the measurement of near-end cross-talk between (1) AB and CD, (2) the phantom and AB or CD.

The resistances between the stops of this meter can be altered, if required, so that the dial is graduated in decibels instead of millionths.

All measurements can be carried out using actual speech to produce the disturbing voltage V_s instead of a mixed tone generator or oscillator.

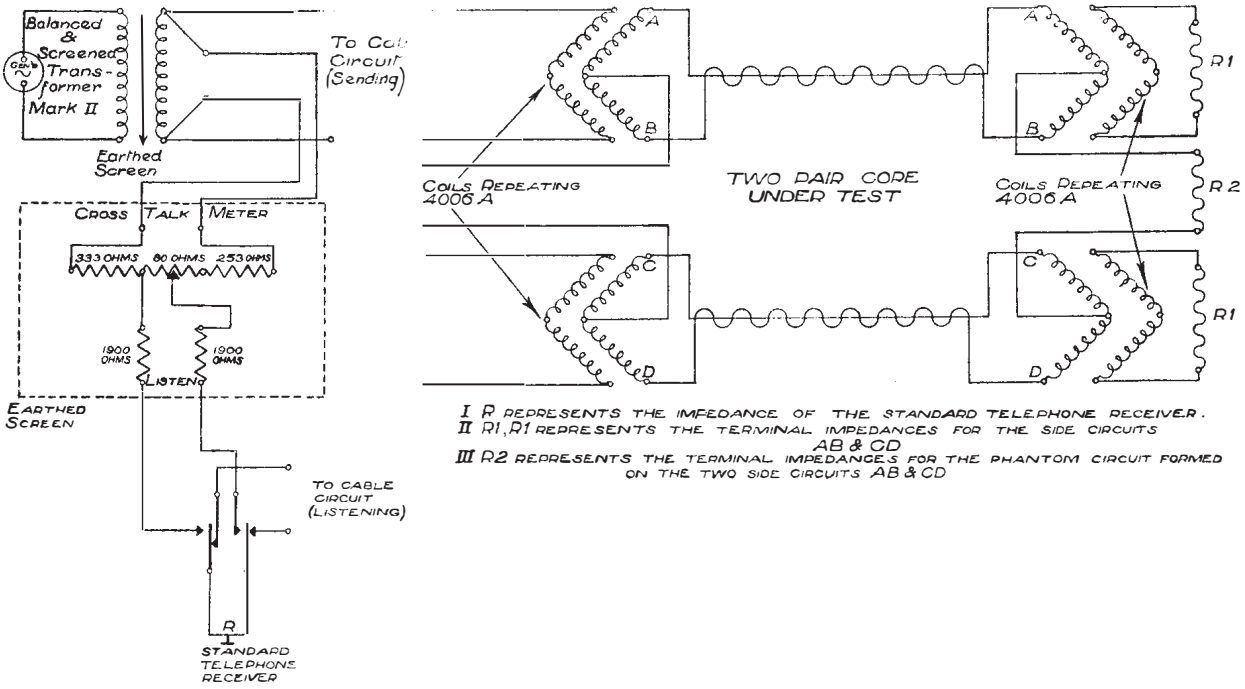


FIG. **38**.—WESTERN ELECTRIC CROSS-TALK METER.

Correction Factors for Cross-Talk Measurements—Meter in Parallel.—In those cases where the disturbed circuit AB has not the same impedance as the disturbed circuit CD, it follows that the ratio $\left(\frac{V_s}{V_r}\right)^2$ does not represent a true power ratio. A correction to the cross-talk meter reading will therefore be necessary.

In Fig. **37**,

Let Z_s = characteristic impedance of the disturbing circuit AB, and with which it is terminated.

Z_r = characteristic impedance of the disturbed circuit CD, and with which it is terminated.

Then the cross-talk between AB and CD is the ratio of the power received (P_r) at CD to the power sent (P_s) at AB. This can be expressed as an attenuation:—

$$\frac{P_r}{P_s} = e^{-2\beta} \quad \ldots\ldots(1)$$

Let Z_t = impedance of the telephone

V_0 = voltage appearing at CD when that branch is open,

Then by *Thevenin's Theorem* (See pp. (*h*) of Notes for Addition to Section I) the current in the branch CD when closed by Z_r is

$$\frac{V_0}{Z_r + Z_r} = \frac{V_0}{2Z_r} \quad . \quad \text{Hence:—}$$

$$P_r = \frac{V_0^2}{4Z_r}$$

$$P_s = \frac{V_s^2}{Z_s}$$

$$\therefore \frac{P_r}{P_s} = \frac{V_0^2}{4V_s^2} \cdot \frac{Z_s}{Z_r} \quad \ldots\ldots(2)$$

From equation (1) and (2)

$$V_0 = 2V_s \cdot \sqrt{\frac{Z_r}{Z_s}} \cdot e^{-\beta} \quad \ldots\ldots(3)$$

The current (I_t) in the branch CD when closed by Z_t is (by Thevenin's Theorem)

$$I_t = \frac{V_0}{Z_r + Z_t} \quad \text{.....(4)}$$

By substitution of equation (3) in (4) for V_0

$\therefore$ I_t (the current obtained for comparison when making cross-talk)

$$= \frac{2V_s}{Z_r + Z_t}\sqrt{\frac{Z_r}{Z_s}} \cdot e^{-\beta}$$

Writing $\frac{V_s}{M_s} = I_m$ where I_m is the current in the meter and M the meter impedance

$$\therefore\ e^{\beta} = \frac{I_m}{I_t}\sqrt{\frac{Z_s}{Z_r}} \times \frac{2Z_r}{Z_r + Z_t} \times \frac{M}{Z_s} \quad \text{.....(5)}$$

$$\text{or } \beta = \log_e \frac{I_m}{I_t} + \tfrac{1}{2}\log_e \frac{Z_s}{Z_r} + \log_e \frac{2Z_r}{Z_t + Z_r} + \log_e \frac{M}{Z_s} \quad \text{.....(5A)}$$

If the telephone and meter each have an impedance made equal to that of the listening and sending circuit respectively, *i.e.*, $Z_t = Z_r$; and $M = Z_s$, then :—

$$e^{\beta} = \frac{I_s}{I_t} \times \sqrt{\frac{Z_s}{Z_r}} \quad \text{.....(6)}$$

Now $\frac{I_t}{I_s} \times 10^6$ is the meter reading; *i.e.*, the correction required to the meter reading is the divisor $\sqrt{\frac{Z_s}{Z_r}} = \sqrt{\frac{\text{Disturbing circuit impedance}}{\text{Disturbed circuit impedance}}}$

Again if $Z_r = Z_s$, as in the case of side-circuit to side-circuit cross-talk measurements :—

$e^{-\beta} = \frac{I_s}{I_t} \equiv$ meter reading; and no correction is required.

Example.—The measured cross-talk between a phantom circuit of impedance 100 ohms and a side-circuit of 400 ohms impedance was 1000 units. Calculate (*a*) the corrected value of the cross-talk and (*b*) the probable meter reading for the side-to-phantom measurement assuming the impedance of the telephone and meter in each case are made equal to that of the listening circuit and sending circuit respectively.

(*a*) Correction factor $= \sqrt{\frac{Z_r}{Z_s}}$ by equation (6).

$\therefore$ True cross-talk $= 1000 \times \sqrt{\frac{400}{100}}$

$= 2000$ units

i.e., the corrected cross-talk is twice the measured value.

(*b*) The correction in this case is

$$\frac{1}{\sqrt{\frac{400}{100}}} = \tfrac{1}{2}.$$

$\therefore$ Meter Reading $\times \frac{1}{2}$ = True Value.

$= 2000$

i.e., Meter reading = 4000 which gives the *corrected cross-talk as half the measured value.*

The necessity for the correction for impedances when quoting cross-talk values for any given cable is thus of great importance if these values are to be used for comparison purposes.

An alternative to the above correction factors is a complicated testing set which gives the equality of impedances required by means of transformers and resistances.

(4) Cross-Fire.

This is the term applied to interference experienced in one telegraph circuit from the working telegraph currents of a neighbouring circuit. Such interference can generally be reduced considerably by suitable terminal devices. The precise measurement for comparison purposes of existing interference is not an easy matter and the question is discussed in detail in papers, references to which are given at the end of Section 10.

(5), (6) and (7). Noise and Power Circuit Interference.

The technique of precisely measuring the extent of interferences of this description is not yet fully developed. The method favoured for "noise" measurement is a comparative method wherein, essentially, the induced noise voltage is compared with an inducing voltage of known characteristic wave-form by means of a potentio-

meter arrangement and the readings obtained on a valve-voltmeter, which can be paralleled alternately with the inducing and induced voltages by the operation of a key. (See references).

Further References for Section 10:—

" Definition and Measurement of Cross-Talk," J. Carvallo, Annales des P.T.T. Sept., 1925. p. 887.

" Telephone Cable Circuit Interference," A. Morris. I.P.O.E.E. Paper No. 126.

" Cable Testing Methods," W. T. Palmer and E. H. Jolly. I.P.O.E.E. Paper read at a London meeting of Institution on 10th Nov., 1931.

" Interference Between Circuits in Continuously Loaded Cables," A. Rosen. J.I.E.E., Vol. 62, 1926. p. 849.

" Neutralization of Telegraph Cross-Fire," R. B. Shanck. Bell System Technical Journal, Vol. V., 1926. p. 418.

" Interference Between Power and Communication Circuits." Summary of Recent Information (1926-29), by W. G. Radley. J.I.E.E., Vol. 69, Sept., 1931. p. 1117.

SECTION 11.

The European Master Reference System.

A Master Reference System is a laboratory transmission circuit used as a fundamental base with which to compare the transmission performance (*i.e.*, any or all of the factors outlined in Section 10) of sub-standard reference systems and actual telephone circuits. It can also be used to compare the performance of sub-standard and actual transmitters and receivers with that of the reference transmitter and receiver.

The reference system itself consists essentially of an artificial line, a condenser transmitter and a moving-coil type of receiver. The performance of the complete system can be stated by comparing the pressure (in dynes per sq. cm.) produced by the receiver with the pressure on the diaphragm of the transmitter and is practically free from distortion, although it can be arranged to imitate any type of distortion desired. Noise effects can also be introduced without otherwise affecting the system.

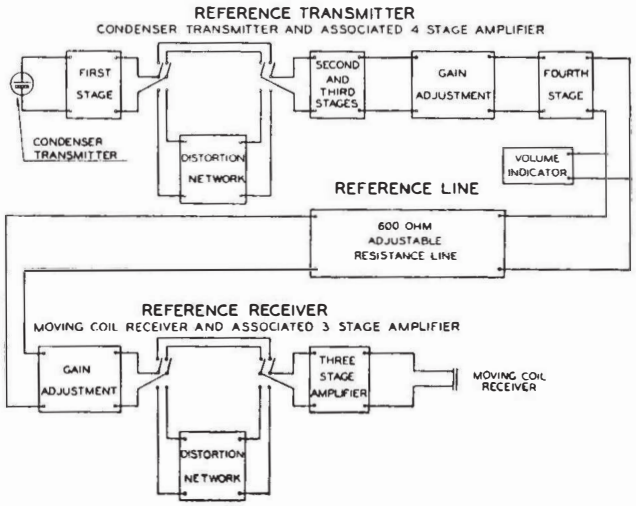


FIG. 39.—SCHEMATIC DIAGRAM OF MASTER REFERENCE SYSTEM.

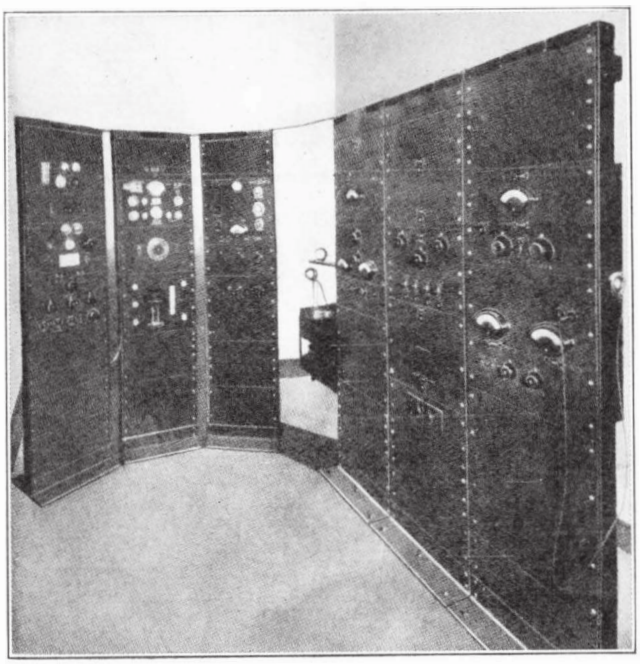


FIG. 40.—MASTER REFERENCE SYSTEM WITH ASSOCIATED CALIBRATION APPARATUS.

Fig. **39** is a schematic diagram of the arrangement and Fig. **40** is a photograph of the European Master Reference System installed in Paris, (a replica of the American Master Reference System).

Reference for Section 11:—

" Master Reference System for Telephone Transmission," W. H. Martin and C. H. G. Gray. Bell Technical Journal, July, 1929. pp. 536-559.

SECTION 12.

Electrical Wave Filters.

Adverting to Section 8, the networks there considered have an interest apart from their use as artificial lines since, as will be seen in this Section, they may be used as electric wave filters. The three principal types are as follows:—

(1) Low Pass Filter.

This is a network which only passes freely frequencies *below* a certain value called the "*cut-off.*"

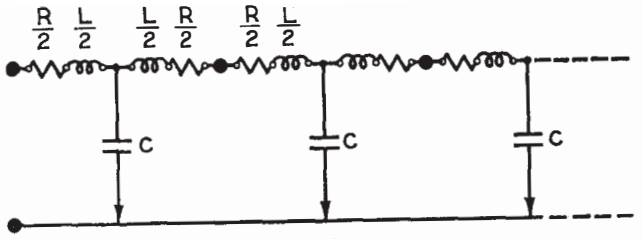


FIG. 41.—LOW PASS FILTER.

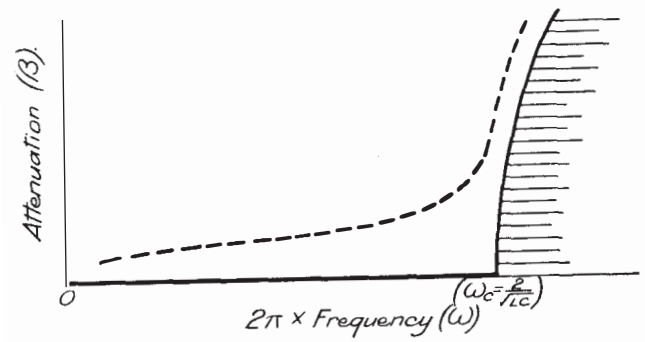


FIG. 42.—LOW PASS FILTER.
The shaded portion represents the non-transmitted range in the resistanceless case.

Consider Fig. **41** which represents a number of **T**-recurrent networks. By equation (15) of Section 8 we have:—

$$\text{Cosh P} = 1 + \frac{Z_1}{Z_2}$$

where $Z_1 = \frac{1}{2}(R + j\omega L)$

$Z_2 = 1/j\omega C$

P = the propagation constant per section

Let $P = \beta + j\alpha$

$\therefore$ Cosh P = cosh $\beta \cdot \cos\alpha + j \sinh\beta \sin\alpha$ (See pps. (*d*) and (*g*), Section 1).

$$\therefore \text{Cosh}\,\beta\cos\alpha + j\sinh\beta\sin\alpha = 1 + \frac{Z_1}{Z_2}$$

$$= 1 + \frac{\frac{1}{2}(R + j\omega L)}{1/j\omega C}$$

i.e., Cosh $\beta \cos\alpha + j \sinh\beta \sin\alpha = 1 - \frac{1}{2}\omega^2 LC + \frac{1}{2} j\omega CR$.

To study the effect of frequency on the attenuation, β, neglect R and then equating real and imaginary parts of this last expression we get:—

$$\text{Cosh}\,\beta\cos\alpha = 1 - \tfrac{1}{2}\omega^2 LC \quad \ldots\ldots(1)$$

$$\text{Sinh}\,\beta\sin\alpha = 0 \quad \ldots\ldots(2)$$

By equation (2) we have either sinh $\beta = 0$ or $\sin\alpha = 0$.

i.e., if $\beta = 0$ (the network passing the electric energy freely with *no attenuation*) then cosh $\beta = 1$ and hence by equation (1):—

$$\text{Cos}\,\alpha = 1 - \tfrac{1}{2}\omega^2 LC.$$

This expression is possible from zero up to the value of ω which just makes $\cos\alpha = -1$ and above this value it is inadmissible since *cos* α cannot be more negative than -1.

$\therefore$ the highest permissible value of ω (written as ω_c) is given by:—

$$1 - \tfrac{1}{2}\omega_c^2 LC = -1$$

$$i.e., \quad \omega_c = \frac{2}{\sqrt{LC}} \quad \ldots\ldots(3)$$

Equation (3) gives what is termed the **"cut-off" frequency.**

Below this frequency the attenuation is zero, and α changes from 0 to π (*i.e.*, cos α from $+1$ to -1) as ω goes from zero to ω_c and remains π above ω_c. Above the value ω_c we have ($\alpha = \pi$) $\sin\alpha = 0$ and hence by equation (1):—

$$-\text{Cosh}\,\beta = 1 - \tfrac{1}{2}\omega^2 LC.$$

In other words β increases rapidly above ω_c. The full curve shows this effect, in Fig. **42**, whilst the dotted curve shows the effect of resistance, which is: (1) rounds off the sharp corner at ω_c and (2) gives a finite value to the attenuation throughout the frequency range below "cut-off."

Important Note.—Comparing the dotted curve in Fig. **42** with those for the attenuation of coil-

loaded lines in Fig. **27**, Section 9, the similarity will be evident. Equation (5) of Section 9 should also be compared with the above equation (3) and *thus a coil-loaded line can be considered as a low-pass filter* (having each loading section as one section of the network) with distributed resistance in each section.

(2) High Pass Filter.

This is a network which passes freely only frequencies *above* a certain value called the "*cut-off*."

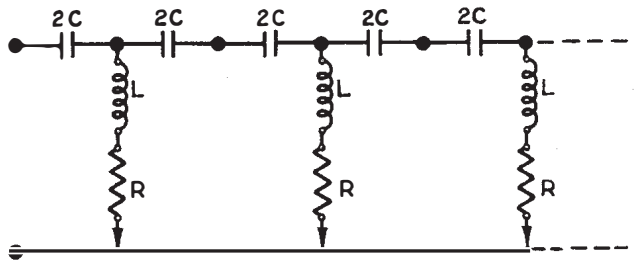


FIG. **43**.—HIGH PASS FILTER.

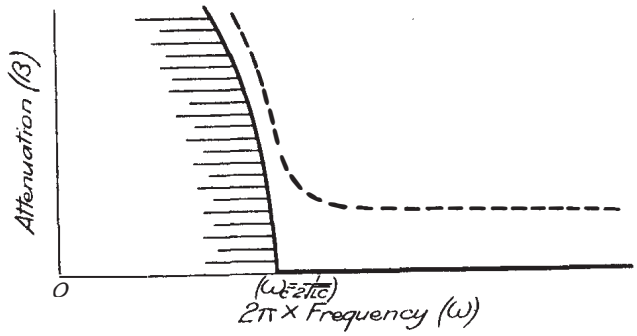


FIG. **44**.—HIGH PASS FILTER.
The shaded portion represents the non-transmitted range in the resistanceless case.

Consider Fig. **43** which represents a number of **T**-recurrent sections. In this case, by equation (15) of Section 8:—

$$\text{Cosh } P = 1 + \frac{Z_1}{Z_2}$$

$$\therefore \quad \text{Cosh } (\beta + j\alpha) = 1 + \tfrac{1}{2}\left(-\frac{j}{\omega C}\right)\left(\frac{1}{R + j\omega L}\right)$$

As in the previous case, by equating real and imaginary parts and neglecting resistance we get:—

$$\text{Cosh } \beta \cos \alpha = 1 - \frac{1}{2\omega^2 LC} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$\text{Sinh } \beta \sin \alpha = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Hence by equation (5) if sinh $\beta = 0$, cosh $\beta = 1$, and equation (4) becomes:—

$$\text{Cos } \alpha = 1 - \frac{1}{2\omega^2 LC}$$

Due to the trigonometrical ratio this last equation is only possible for high values of ω and the lowest permissible value of ω, viz., ω_c, is given by:—

$$1 - \frac{1}{2\omega_c^2 LC} = -1$$

$$i.e., \quad \omega_c = \frac{1}{2\sqrt{LC}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

This is termed the "**cut-off**" **frequency** since the network allows frequencies higher than ω_c to pass readily (see the full curve in Fig. **44**), but greatly attenuates the lower frequencies.

The phase constant, α, changes from 0 to π as ω decreases from a very high value down to ω_c, *i.e.*, cos α changes from $+1$ to -1. The effect of resistance is to round off the corner at ω_c as shown by the dotted curve in Fig. **44**.

(3) Band Pass Filter.

The network considered here is one which will pass freely only a band of frequencies lying between two certain values, the frequencies below and above this band being greatly attenuated.

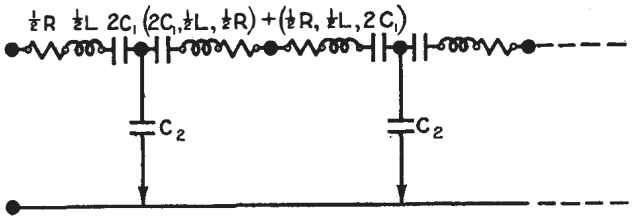


FIG. **45**.—BAND PASS FILTER.

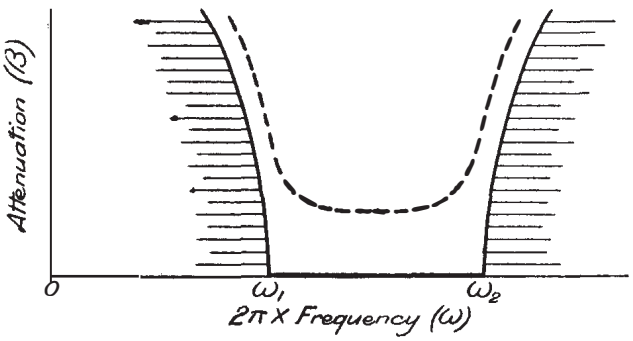


FIG. **46**.—BAND PASS FILTER.
The shaded portions represent the non-transmitted ranges in the resistanceless case.

From Fig. **45** and equation (15) of Section (8) we have :—

$$\text{Cosh } P = \cosh(\beta + j\alpha) = 1 + \tfrac{1}{2}\left(R + j\omega L + \frac{1}{j\omega C_1}\right)(j\omega C_2)$$

$$= 1 - \tfrac{1}{2}\omega^2 LC_2 + \frac{C_2}{2C_1} + \tfrac{1}{2} j\omega C_2 R$$

As in the foregoing cases the cut-off frequency can be obtained by :—

$$\text{Cosh } \beta \cos \alpha = 1 - \tfrac{1}{2}\omega^2 LC_2 + \frac{C_2}{2C_1} \quad \ldots\ldots(7)$$

$$\text{Sinh } \beta \sin \alpha = 0 \quad \ldots\ldots(8)$$

With $\beta = 0$, then :—

$$\text{Cos } \alpha = 1 - \tfrac{1}{2}\omega^2 LC_2 + \frac{C_2}{2C_1}$$

This equation is obviously impossible for very high values of ω and for very low values due to the trigonometrical ratio, cos α. The limiting values, ω_1 and ω_2, of the band for which the equation holds is obtained from the quadratic :—

$$1 - \tfrac{1}{2}\omega^2 LC_2 + \frac{C_2}{2C_1} = \pm 1$$

$$\therefore \quad \omega_1 = \frac{1}{\sqrt{LC_1}} \quad \text{and} \quad \omega_2 = \sqrt{\frac{4}{LC_2} + \frac{1}{LC_1}}$$

From ω_1 to ω_2 the phase constant, α, changes from 0 to π and remains π from ω_2 upwards, being zero for values below ω_1.

Fig. **46** shows the attenuation characteristics for the ideal, or resistanceless, case by the full curve. The dotted curve shows the rounding-off due to resistance and the finite, though small, attenuation throughout the band transmitted.

The Design of Filter circuits is generally concerned, in addition to the cut-off frequency, with the impedance of the circuit in which the filter is to be introduced; and, generally speaking, to avoid reflection losses the filter impedance has to be designed to be equal to the circuit impedance it terminates or subjoins.

The Uses of Filter circuits for transmission purposes are manifold, and the student is strongly advised to consult the references given at the end of this Section for details concerning the important questions of design and application of electrical filters. Amongst the most important applications are :—

(1) For insertion in series with an A.C. supply to eliminate as far as possible unwanted higher harmonics and thus obtain a relatively " pure " fundamental supply frequency.

(2) For separating a number of " mixed " frequencies into the constituent frequencies of the " mixed " wave received, as in carrier-current telephony, voice-frequency telegraphy,

(3) For transmitting efficiently only a certain required " band " of frequencies as in some telephone repeater circuits, etc.

Useful References for Section 12 :—

" Electrical Filters," A. B. Morice. Phil. Mag. (Supplement), April, 1927. pp. 801-843.

" Transmission Characteristics of Electric Wave Filters," O. J. Zobel. Bell System Technical Journal, Oct., 1924. pp. 567-620.

" Impedance Correction of Wave Filters," E. B. Payne. Bell System Technical Journal, Oct., 1930. pp. 794-835.

" The Design of Filters for Audio Frequencies," C. A. Beer and G. J. S. Little. P.O.E.E.J., Jan., 1925. pp. 298-317.

" Electric Wave Filters," O. J. Zobel. Bell System Technical Journal, April, 1931. pp. 284-341.

SECTION 13.—TELEPHONE REPEATERS.

(Notes to be continued.)

STAFF CHANGES.

POST OFFICE ENGINEERING DEPARTMENT.

PROMOTIONS.

Name.	From	To	Date.
Mercer, C. J.	Assistant Staff Engineer, Radio Section, E.-in-C.O.	Staff Engineer, Telegraph Section, E.-in-C.O.	13-12-31
Timmis, Capt. A. C.	Executive Engineer, Research Section, E.-in-C.O.	Assistant Staff Engineer, Research Section, E.-in-C.O.	1-11-31
Aldridge, A. J.	Executive Engineer, Research Section, E.-in-C.O.	Assistant Staff Engineer, Research Section, E.-in-C.O.	1-2-32
De Wardt, R. G.	Executive Engineer, Radio Section, E.-in-C.O.	Assistant Staff Engineer, Telegraph Section, E.-in-C.O.	9-10-31
Steward, W.	Executive Engineer, Dundee Section, Scot. East District.	Assistant Suptg. Engineer, N.E. District.	25-10-31
Barnes, E. J.	Assistant Engineer, Research Section, E.-in-C.O.	Executive Engineer, Research Section, E.-in-C.O.	1-11-31
Tissington, Capt. H. G.	Assistant Engineer, N. Mid. District.	Executive Engineer, Dundee Section, Scot. E. District.	21-10-31
Beer, C. A.	Assistant Engineer, Research Section, E.-in-C.O.	Executive Engineer, Research Section, E.-in-C.O.	1-2-32
Warren, A. C.	Assistant Engineer, Radio Section, E.-in-C.O.	Executive Engineer, Radio Section, E.-in-C.O.	9-10-31
Arnold, A.	Chief Inspector, Research Section, E.-in-C.O.	Assistant Engineer, Research Section, E.-in-C.O.	1-11-31
Griffiths, W. R.	Executive Officer, Stores Department.	Motor Transport Officer, Class II.	
Bunt, F. H. J.	Draughtsman, Cl. I., E.-in-C.O.	Motor Transport Officer, Class III.	
Chapman, E.	Clerical Officer, Stores Department.	,, ,, ,, ,,	
Collman, E. L.	Inspector, Engineering Department.	,, ,, ,, ,,	
Palser, F. D.	Clerical Officer, Stores Department.	,, ,, ,, ,,	
Ransley, C. C.	Executive Officer, Stores Department.	,, ,, ,, ,,	
Salter, F. J.	Executive Officer, Stores Department.	,, ,, ,, ,,	
Wright, F. V.	Assistant Engineer, E.-in-C.O.	,, ,, ,, ,,	
Malcolm, A. L.	Executive Officer, Stores Department.	Area Transport Officer, London.	
Unitt, A. T. G.	Executive Officer, Stores Department.	,, ,, ,, ,,	
Allen, J. E.	Overseer, Sheffield Post Office.	Area Transport Officer, Provinces.	
Ball, F. T.	Clerical Officer, Stores Department.	,, ,, ,, ,,	
Daft, W. E.	Overseer, Loughborough Post Office.	,, ,, ,, ,,	
Gregson, A.	Inspector, Engineering Department.	,, ,, ,, ,,	
Marks, R.	Executive Officer, Stores Department.	,, ,, ,, ,,	
Townsend, S. B.	Assistant Engineer, E.-in-C.O.	,, ,, ,, ,,	
Withers, C. A.	Clerical Officer, Engineering Dept.	,, ,, ,, ,,	
Wood, E. W.	Executive Officer, Stores Department.	,, ,, ,, ,,	
Dyson, C. E. J. C.	Clerical Officer, Engineering Dept.	Acting Executive Officer.	
Clothier, W.	Inspector, Engineering Department.	Technical Assistants.	
Coventon, A. E.	Skilled Workman, Class I., Engineering Department.	,, ,,	
Dunn, C.	Mechanic-in-Charge, Stores Dept.	,, ,,	
Huxley, R. T.	Inspector, Engineering Department.	,, ,,	
Finlayson, J. W.	Mechanic-in-Charge, Stores Dept.	,, ,,	
Finney, C. W. M. S.	Inspector, Engineering Department.	,, ,,	
Grover, E.	Storekeeper, Stores Department.	,, ,,	
Stokes, F. W....	Mechanic-in-Charge, Stores Dept.	,, ,,	
Webster, H. R. F.	Mechanic-in-Charge, Stores Dept.	,, ,,	
West, P. S.	Mechanic-in-Charge, Stores Dept.	,, ,,	

Area Transport Officers and Motor Transport Officers Class III. will be regarded as of equal status and eligibility for promotion to Class II posts.

REVERSION AT OWN REQUEST.

Name.	From	To	Date
White, H. W.	Executive Engineer, London District.	Assistant Engineer, E.-in-C.O.	10-11-31

RETIREMENTS.

Name.	Rank.	District.	Date.
Batchelor, D.S.O., M.C., Major W. M.	Superintending Engineer.	S.W. District.	31-10-31
Pusey, A. E.	Inspector.	London.	31-8-31
Burnside, J.	,,	Scotland East.	28-8-31
Bancroft, R.	,,	S. Mid.	17-9-31
France, G. S.	Executive Engineer.	S. Wales.	30-9-31
Gingell, H.	Inspector.	S. Mid.	31-7-31
Bowie, J.	Chief Inspector.	Scotland West.	31-12-31
Adams, E.	,,	S. Mid.	27-10-31
Cruickshank, W.	Assistant Staff Engineer.	Research Section, E.-in-C.O.	31-10-31
Paterson, J.	Chief Inspector.	Scotland East.	3-11-31
Halton, R.	Assistant Staff Engineer.	Lines Section, E.-in-C.O.	4-11-31
Warner, A.	Executive Engineer.	London.	31-10-31
Beetlestone, M.A.	Assistant Engineer.	London.	4-12-31
West, G. E.	Assistant Engineer.	London.	31-10-31
Booth, Lieut.-Col A. C.	Staff Engineer.	Telegraph Section, E.-in-C.O.	11-12-31

DEATHS.

Name.	Rank.	District.	Date.
De Medewe, J. L.	Inspector.	S. Wales.	24-7-31
Moore, F.	Inspector.	London.	20-8-31
Hardaker, W. H.	Chief Inspector.	N. East.	9-11-31

TRANSFERS.

Name.	Rank.	From	To	Date.
Horn, C. O.	Assistant Engineer.	E.-in-C.O.	N. Mid. District.	15-11-31

CLERICAL ESTABLISHMENT.

PROMOTIONS.

Name.	From	To	Date.
Cramp, T. E.	Clerical Officer, S. Lancs. District.	Higher Clerical Officer, S. Lancs. District.	20-10-31
Bosher, M. E.	Clerical Officer, Eastern District.	Higher Clerical Officer, Eastern District.	25-9-31
Halsall, T. G.	Clerical Officer, S. Lancs. District.	Higher Clerical Officer, N. West District.	4-10-31
Restall, A. T.	Clerical Officer, London District.	Higher Clerical Officer, London District.	1-10-31
Gold, R. J. S.	Staff Officer, E.-in-C.O.	Princ. Clerk, E.-in-C.O.	14-10-31
Laws, W.	Executive Officer, E.-in-C.O.	Staff Officer, E.-in-C.O.	14-10-31
Oliver, S. R.	Clerical Officer, E.-in-C.O.	Acting Executive Officer, E.-in-C.O.	14-10-31
Murray, C. E.	Acting Executive Officer, E.-in-C.O.	Executive Officer, E.-in-C.O.	14-10-31
Bradley, E.	Clerical Officer, London District.	Higher Clerical Officer, London District.	1-11-31
Gibbard, W. E.	Clerical Officer, S. Mid. District.	Higher Clerical Officer, S. Western District.	30-11-31
James, W.	Clerical Officer, S. Eastern District.	Higher Clerical Officer, S. Eastern District.	11-12-31
Hopkinson, J.	Clerical Officer, N. Wales District.	Higher Clerical Officer, Eastern District.	16-11-31

RETIREMENTS.

Name.	Rank.	District.	Date.
Green, G. H.	Higher Clerical Officer.	S. Lancs.	19-10-31
Smith, G. R.	Higher Clerical Officer.	Eastern.	24-9-31
Hemming, J. G.	Higher Clerical Officer.	N. Eastern.	2-10-31
Cole, G. G.	Executive Officer.	L.E.D.	30-9-31
Haves, A. H.	Higher Clerical Officer.	L.E.D.	31-10-31
Renshaw, A. S.	Princ. Clerk.	E.-in-C.O.	13-10-31
Grant, J. A.	Higher Clerical Officer.	S. Western.	15-11-31
Gillett, B. F.	Higher Clerical Officer.	S. Eastern.	11-12-31
Cowley, W. H.	Higher Clerical Officer.	Eastern.	16-11-31
McCormack, H. C.	Staff Officer.	S. Mid.	31-12-31
Smith, W. B.	Higher Clerical Officer.	N. Ireland.	27-11-31

TRANSFERRED.

Name.	From	To	Date.
Evered, F. M.	Higher Clerical Officer, N. Western District.	Higher Clerical Officer, N. Eastern District.	4-10-31
Ransley, C. C.	Executive Officer, Stores Dept.	Executive Officer, E.-in-C.O. (M/T)	14-10-31
Griffiths, W. R.	,, ,, ,,	,, ,, ,, ,,	
Salter, F. J.	,, ,, ,,	,, ,, ,, ,,	
Malcolm, A. L.	,, ,, ,,	,, ,, ,, ,,	
Unitt, A. T. G.	,, ,, ,,	,, ,, ,, ,,	
Weston, A. S.	,, ,, ,,	,, ,, ,, ,,	
Marks, R.	,, ,, ,,	,, ,, ,, ,,	
Wood, E. W.	,, ,, ,,	,, ,, ,, ,,	
Pursall, S.	Higher Clerical Officer, Stores Dept.	Higher Clerical Officer, E.-in-C.O (M/T)	

DECEASED.

Name.	Rank.	District.	Date.
Patrick, J.	Higher Clerical Officer.	Scotland East.	29-10-31

BOARD OF EDITORS.

B. O. ANSON, M.I.E.E., Chairman.

P. J. RIDD, M.I.E.E.

H. KITCHEN, M.I.E.E.

A. J. GILL, B.Sc., M.I.E.E., M.I.R.E.

J. D. BOULTON.

J. T. KELLY.

W. CRUICKSHANK, M.I.E.E., Managing Editor.

J. INNES, B.Sc., A.M.I.E.E., Assistant Editor.

COMMUNICATIONS.

All Remittances and Communications should be addressed to the MANAGING EDITOR, P.O.E.E. JOURNAL, Engineer-in-Chief's Office, Alder House, London, E.C.1.

Binding covers and copies of the Contents for Vol. 3 to 23 are available, and may be obtained from the local agents for 1*s.* 6*d.* and 3*d.* respectively. Subscribers can have their copies of Vol. 23 bound, with index included, at a cost of 3*s.*, by sending the JOURNALS to the local agents. Orders for bindings, Vols. 1—19, should indicate whether the original binding with black lettering, or the latter pattern in gold, is required. Covers with gold lettering will be the only type stocked from Vol. 20 onwards.

The price of the JOURNAL is 1*s.* (1*s.* 3*d.* post free) per copy, or 5*s.* per annum, post free. All back numbers 2*s.* each.

POST OFFICE ELECTRICAL ENGINEERS' JOURNAL.

Volume XXIV—April 1931 - March 1932.

INDEX.

PAGE

A.

Acorn Exchange: Open Type Racks. B. H. Brown 17, 113, 197, 274
Aerial Cable Construction, Trunk Line 213
Agra Telegraph Office, The equipment of. Frome ... 1
Alexander, R. Death of 183
All-Mains Teleprinter Duplex Set. A. Arnold and Denman 103
Anglo-French (1930) Submarine Telephone Cable, The. F. E. A. Manning 37
Anson, B. O. Promotion to Staff Engineer 179
Australia, Commonwealth of. Annual Report 252
" Speed of Signal Transmission over Carrier Telegraph Channels 269

B.

Back-to-Back Testing of Exchange Motor Generators. R. MacWhirter 49
Batchelor, Major W. M., D.S.O., M.C., Retirement of ... 316
Bailey, W. J. Retirement of 179
Beams, Radio 59
Beard, A. T. J. Fascimile Transmission in the U.K. ... 4
Birmingham, Introduction of Auto. Telephone System at 110
Board of Editors 96, 192, 268, 330
Book Reviews 90, 188, 254, 318
Booth, Lt.-Col. A. C., Retirement of 329
Brighton Aerial Cable 213
Brown, B. Houghton. Acorn Exchange ... 17, 113, 197, 274
Brown, J. Retirement of 249
Buildings, Ventilation of Auto Exchanges 46
Bypath Auto. Telephone System, The. Wright and Baker 116

C.

Cable, A robust Main 317
Cable, The Anglo-French (1930) Submarine 37
Cable Pairs, Locating Crosses in 71, 169
Cable, The Transandean Telephone 140
Cable, Trunk Line Aerial 213
Canada, Telephone Development 65
Characteristics of Condenser Transmitters and Moving Coil Receivers, Frequency 27
Carr, A. S. Preston Multi Exchange Area 200
Civic Party at Opening of Newcastle-on-Tyne Auto. System 75
Carrier Telegraph Channels. Speed of Signal Transmission over 269
Cohen, Capt. B. S. Engineering Research in the Post Office 6
Common Control System. Taylor and Beale 125
Commonwealth of Australia. Annual Report 253
Communications 96, 192, 268, 330
Concrete Poles for Tropical Use, Reinforced 135
Condenser Transmitters, Frequency Characteristics ... 27
Control Equipment, Frequency. P.O. Short Wave Transmitters 159, 228
Covered Drop Wire Equipment for Subscribers Distribution 219
Craddock, G. W. and Brent, W. H. Trunk Line Aerial Cable Construction 213
Crosses in Split Cable Pairs, Locating the 71, 169
Continuously Loaded Cable for H.F., A 295
Cruickshank, W. Retirement of 308

PAGE

D.

Dallow, J. C. The Grub Menace 131
Demand Trunk Service. I. H. Jenkins 193
Development, Telephone Lines in Canada 65
Development in the Use of Very Short Radio Waves ... 152
Distribution, Covered Drop Wire for Subscribers ... 219
District Notes 69, 181
Diversion of P.O. Plant, Guildford 311
Dixon, E. J. C. Frequency Control Equipment ... 159, 228
Drop Wire Distribution, Covered 219

E.

Economies 60 years ago 304
Efficiency Tester, The Telephone Instrument 31
Engineering Research in the Post Office. Capt. B. S. Cohen 6
Erection of Poles by Crane on 3-ton lorry 313
Essay Competition 257
Exchanges. Acorn. B. H. Brown... ... 17, 113, 197, 274
Exchanges, Equipment and Installation, Headquarter's Notes 67, 173, 243, 306
Exchanges, Newcastle-on-Tyne 22, 75

F.

F., J. E. Drop Wire Distribution 221
Facsimile Transmission in the United Kingdom. Beard... 4
Faraday, Michael 97, 239
Federated Malay States 253
Flux, Magnetic. An Oscillographic Method of Recording 206
Frequency Characteristics of Standard Reference Type Condenser Transmitters and Moving Coil Receivers. W. West 27
Frequency Control Equipment of P.O. Short Wave Transmitters. E. J. C. Dixon 159, 228
Frequency Measurement in the British P.O. F. E. Nancarrow 155
Frome, N. F. The Equipment of Agra Telegraph Office 1
Finder Development in P.O. Service Line 276
Further Problems in Automatic Trunking. Hawkins ... 289

G.

Gas Leak Indicator, The Hot Wire 221
George Bernard Shaw 63
Gibbon, A. O. Michael Faraday 97
Grass Margins, Underground Work in 73
Grub Menace, The. J. C. Dallow 131
Guildford. Diversion of Plant 311

H.

Halton, R. Retirement of 306
Harper, E. Reinforced Concrete Poles for Tropical Use 135
Harris, L. H. Oscillographic Method of recording Magnetic Flux 206
Hart, A. B. Assistant Engineer-in-Chief 177
Hawkins. Further Problems in Auto Trunking 289
Headquarter's Notes 67, 170, 243, 306
Hines, Capt. J. G. Promotion to Staff Engineer 178
Hot Wire Gas Leak Indicator, The. Richards and Mower 221
Hudson, W. The Telephone Instrument Efficiency Tester 31
Heptode Valve, The. E. J. C. Dixon 299

PAGE

I.

Indicator, The Hot Wire Gas Leak 221
Institution of P.O. Electrical Engineers, The 86, 184, 255, 319
Introduction of Auto. Telephone System at Newcastle-on-Tyne. W. A. Stradling and H. Sadler 22
Introduction of Auto. Telephone System at Birmingham 110

J.

Jenkins, I. H. Demand Trunk Service 193

K.

Kitchen, H. Promotion to Superintending Engineer ... 246

L.

Laying of three 4″ pipes across River Ouse 312
Line Finder Development in British P.O. Service... ... 276
Local Centre Notes 86, 185, 250, 319

M.

MacWhirter, R. Testing of Exchange Motor Generators 49
Malay States, Federated. Annual Report 253
Manning, F. E. A. The Anglo-French (1930) Submarine Telephone Cable 37
Markwick, J. J. Retirement of 180
McGregor, J. E. Ventilation of Buildings 46
Measurement, Frequency in the British P.O. 155
Michael Faraday. Gibbon 97
Motor Generators, Back-to-Back Testing of 49

N.

Nancarrow, F. E. Frequency Control Equipment ... 159
Newcastle-on-Tyne, Introduction of Auto Telephone System 22
Notes and Comments 63, 165, 239, 303
Notes, District 69, 181, 248, 310
Notes, Headquarter's 67, 170, 243, 306
Notes, Local Centre 86, 185, 250, 319

O.

Oscillographic Method of Recording Magnetic Flux, An. L. H. Harris 206
Outline Notes on Telephone Transmission Theory. W. T. Palmer 79, 143, 258, 321
Oxford University: Summer Course for Teachers ... 68

P.

P., R.W. Proposed P.O. Standard Telephone Relay ... 201
Palmer, W. T. Outline Notes on Telephone Transmission Theory 79, 143, 258, 321
Per Ardua ad Astra 247
Plant in the U.K. Telegraph and Telephone 16, 115, 212, 273
Poles, Reinforced Concrete, for Tropical Use 135
Preston Multi-Exchange Area. A. S. Carr 200
Principles of Radio Tower Design. T.W. 231
Problems in Automatic Trunking, Further 289

R.

Radio Beams. T. Walmsley 59
Radio Tower Designs, Principles of 231
Radio Waves, Developments in the Use of Very Short ... 152
Radio Telephony Terminal, The. W. H. Scarborough... 53
Rats for drawing Wires in Ducts 66, 165, 242
Receivers, Moving Coil. Frequency Characteristics of... 27
Reinforced Concrete Poles for Tropical Use. E. Harper 135

PAGE

Research in the Post Office, Engineering 6
Relay, Proposed P.O. Standard Telephone, for Auto Exchanges 201
Richards, C. E. and Mower, G. Hot Wire Gas Leak Indicator 221
River Ouse, Laying of three 4″ pipes across 312
Roach, C. G. Retirement of 72
Robust Main Cable, A 317
R.W.P. Proposed P.O. Standard Telephone Relay ... 201

S.

Sadler, H. Introduction of Auto. Telephone System at Newcastle-on-Tyne 22
Scarborough, W. The Radio Telephony Terminal ... 53
Selling by Telephone 133
Service, Demand Trunk 193
Shaw, George Bernard 64
Short Radio Waves, Developments in the Use of Very ... 152
Staff Changes 94, 189, 265, 328
Strading, W. A. Introduction of Auto Telephone System at Newcastle-on-Tyne 22
Standard Telephone Relay for Auto Exchanges, Proposed P.O. 201
Summer Course for Engineering Teachers at Oxford University 68
Shaughnessy, E. H. Retirement of 174
Speed of Signal Transmission over Carrier Telegraph Channels in Australia 269
Subsidence of Main Cable 317

T.

Taylor, J. D. Retirement of 251
Taylor, R., and Beale, C. E. Common Control System 125
Telegraph Office, The equipment of Agra 1
Telegraph and Telephone Plant in the U.K. 16, 115, 212, 273
Telephone Instrument Efficiency Tester, The. A. Hudson 31
Teleprinter Duplex Set, An All-Mains 103
Transandean Telephone Cable, The 140
Transmission in the United Kingdom, Facsimile 4
Transmission of Wireless Waves of Standard Frequencies from N.P.L. 237
Transmission Theory. Palmer 79, 143, 258, 321
Trunk Line Aerial Cable Construction. Craddock & Brent 213
Trunk Service, Demand 193
Trunking, Further Problems in Automatic 289

U.

Underground Work in Grass Margins 73
Upton, S. Retirement of 315

V.

Valve, A Novel Thermionic. The Heptode 299
Ventilation of Buildings: New System for Use in Auto Telephone Exchanges. J. E. McGregor 46

W.

W., T. Principles of Radio Tower Design 231
Walmsley, T. Radio Beams 59
Waves, Radio. Developments in the Use of Very Short 152
West, W. Frequency Characteristics of Standard Reference Type Condenser Transmitters and Moving Coil Receivers 27
Wheatstone Bridge, A complete solution of the 294
Wood, P. T. Promotion to Superintending Engineer ... 245
Wright, E. P. G. and Baker, J. H. E. Bypath Auto System 116